Exchange Rate Policies at the Zero Lower Bound

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Introduction

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- Central banks responded by implementing policies aimed at weakening their currencies
  - They lowered nominal interest rates, up to zero or even negative numbers
  - They accumulated foreign assets at unprecedented pace

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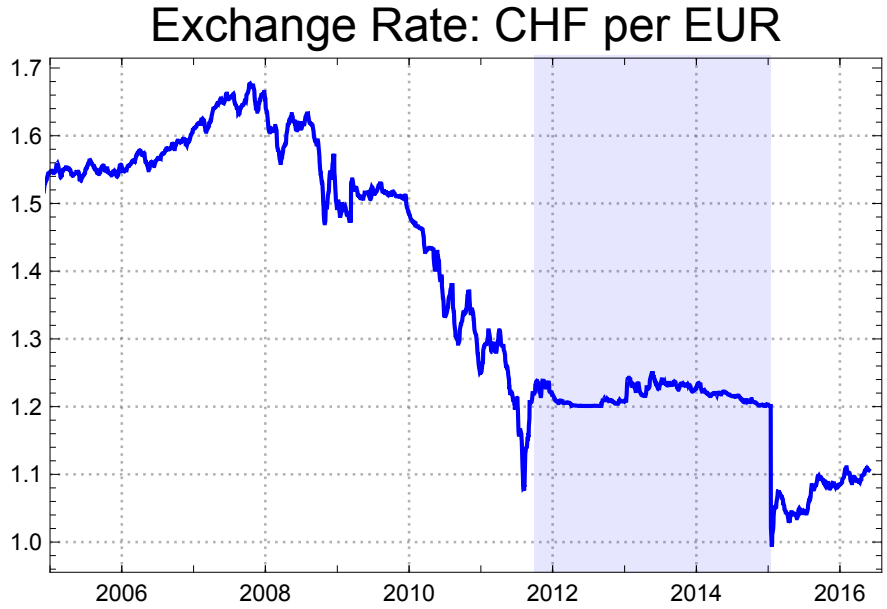
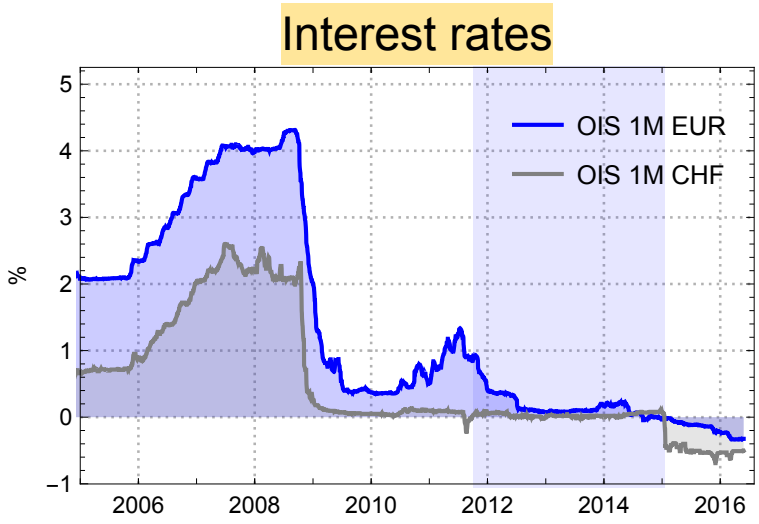
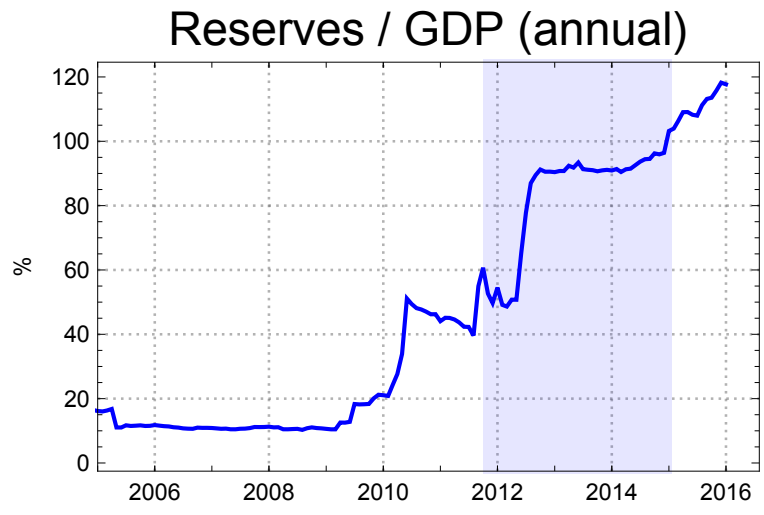
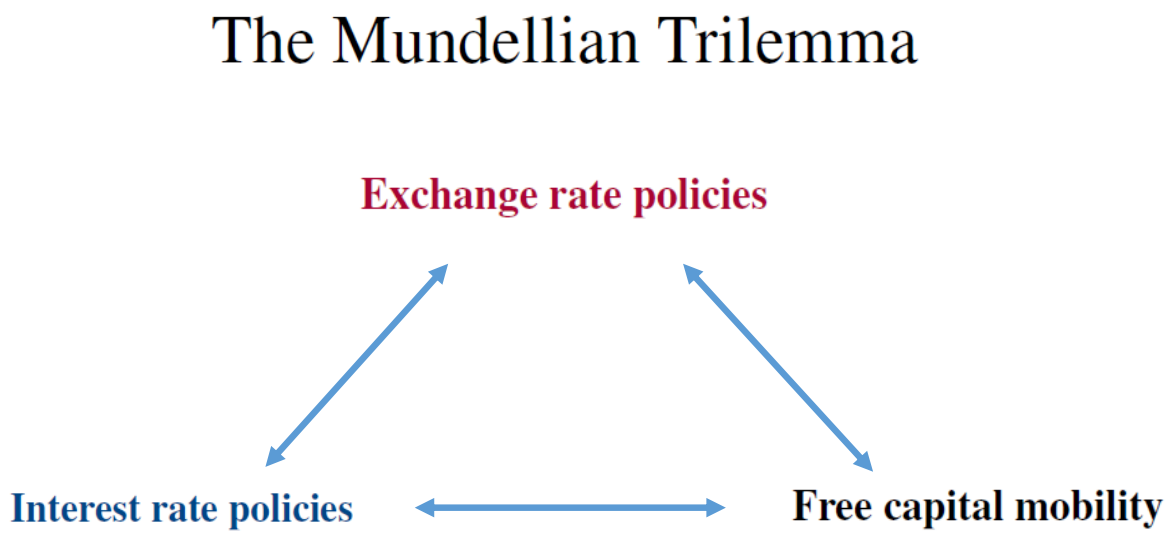
Switzerland







Some basic questions



- How does a Central Bank **implement** a desired exchange rate policy when interest rates are at their lower bound?

- What are the **trade-offs** involved in conducting an independent exchange rate policy in a low nominal interest rate environment?

What we do

- Simple monetary model of exchange rate policy
  - Limited international arbitrage
    - Gabaix-Maggiori(15), Cavallino(16), Fanelli-Straub(15)
  - Zero lower bound (ZLB) constraint for nominal rates
- Characterize policy when the ZLB constraint is slack, and when it binds

Main results

- When ZLB constraint slacks
  - Central Bank can implement exchange rate policy by moving nominal rates
- When ZLB constraint binds
  - Domestic nominal rate cannot adjust for certain policies (e.g. depreciations)
  - Policy necessarily results in a violation of interest rate parity $\Rightarrow$ domestic assets attractive
  - Central Bank sustains policy by accumulating foreign assets. These interventions are **costly**
    - Cavallino (15), Fanelli and Straub (15)
- Capital inflows raise costs of interventions
  - Role for capital controls and negative nominal interest rates
- Cross-country evidence on IP deviations, reserves and interest rates

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Overview of the Talk

1. The Model
2. Implementing an exchange rate policy
   - The role of foreign reserves
   - Implementation when the ZLB constraint is slack, and when it binds
3. Capital inflows and the costs of foreign exchange interventions
4. Optimal exchange rate policies
5. Empirical evidence

The Model

Environment

- Two period small open monetary economy
- Four agents
  1. Households
     - Standard consumption/saving problem, hold money
  2. Foreign investors
     - Buy domestic/foreign assets, and have limited wealth $\bar{w}$
  3. Central Bank
     - Issues money (M), buys domestic/foreign assets (A, F)
     - Implements an exchange rate policy (s_1, s_2)
  4. Fiscal authority
     - Collect taxes and issues domestic debt

Notation

- Price of good abroad constant and normalized at 1
- Exchange rate:
  - s_t = # of domestic currency per foreign currency
- Law of one price holds: $P_t = s_t$
- Nominal interest rate on domestic currency assets: $1 + i$
  - Real interest rate on domestic assets: $1 + r \equiv (1 + i)\frac{s_1}{s_2}$
- Nominal interest rate on foreign currency assets, $1 + i^\star$
  - Zero inflation abroad: $r^\star = i^\star$

Households

$$U(c_1, c_2, m) = \max_{c_1, c_2, f \geq 0, a, m} u(c_1) + h\left(\frac{m}{s_1}\right) + \beta u(c_2)$$

$$\begin{aligned} y_1 + T_1 &= c_1 + \frac{m + a}{s_1} + f \\ y_2 + T_2 &= c_2 - \frac{(1+i)a + m}{s_2} - (1 + i^*)f \end{aligned}$$

- y_t: households endowment, c_t: consumption
- m: money holdings, a: domestic bond holdings, f: foreign assets
- T_t: taxes/transfers from fiscal authority

Interest parity condition

- Euler equation for domestic assets:

$$u'(c_1) = \beta(1+i)\frac{s_1}{s_2}u'(c_2)$$

- And for foreign bonds:

$$u'(c_1) \geq \beta(1+i^\star)u'(c_2)$$

- Equilibrium condition

$$(1+i)\frac{s_1}{s_2} \geq (1+i^*) \qquad \text{([IP])}$$

  - Textbook condition if [IP] holds with equality
  - If inequality strict, households hold only domestic assets ($f = 0$)

Money demand

- Optimality with respect to m:

$$h'\left(\frac{m}{s_1}\right) = \frac{i}{1+i}\frac{u'(c_1)}{s_1}$$

- It implies $i \geq 0$ (ZLB)

Foreign investors

- Invest at home in either assets or money $(a^\star, m^\star)$, or abroad $(f^\star)$
- Linear utility over second period consumption
- Have limited initial wealth $\bar{w}$ and cannot borrow
  - limits to international arbitrage

$$\max_{f^\star \geq 0, a^\star \geq 0, m^\star \geq 0} c^\star$$

subject to:
$$\frac{a^\star + m^\star}{s_1} + f^\star = \bar{w},$$
$$c^\star = (1 + i^\star) f^\star + (1 + i) \frac{a^\star}{s_2} + \frac{m^\star}{s_2}$$

- If [IP] holds with equality, foreigners indifferent between $a^\star$ and $f^\star$
- If [IP] holds as inequality, foreigners invest $\bar{w}$ in domestic assets

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Central Bank

- Pursues an exogenously given exchange rate policy, (s_1, s_2)
- It manages its balance sheet in order to achieve this objective
  - Issues money, $M \geq 0$. Buys foreign reserves $F \geq 0$ and domestic assets A
  - Makes transfers to fiscal authority, (τ_1, τ_2)

$$\begin{aligned} \frac{M}{s_1} &= F + \frac{A}{s_1} + \tau_1 \\ (1+i^\star)F + (1+i)\frac{A}{s_2} &= \frac{M}{s_2} + \tau_2 \end{aligned}$$

Fiscal authority

- Irrelevant
- Collects taxes and transfers
- Issues amount B in domestic nominal bonds (fixed)

Monetary equilibrium given (s_1, s_2)

A monetary equilibrium given the exchange rate policy (s_1, s_2) is: **i)** a domestic nominal interest rate; **ii)** a consumption allocation for households together with asset positions; **iii)** a consumption and asset positions for foreign investors; **iv)** money supply, asset purchases, and transfers by the CB; **v)** and transfers from the fiscal authority to households; such that

1. HH and foreign investors maximize
2. Central Bank and Fiscal authority budget constraints hold
3. Domestic asset markets clear

$$\begin{aligned} m + m^\star &= M \\ a + a^\star + A &= B \end{aligned}$$

Implementing an Exchange Rate Policy

CB interventions in the non-monetary economy

- In order to isolate the role of Central Bank interventions, we consider first the role of F in the non-monetary economy

Non-monetary equilibrium given $F \geq 0$

A domestic real rate r; a consumption allocation and asset demands by HH; and domestic asset demand by foreign investors such that the domestic asset market clears; and foreign investors and households optimize

Non-monetary economy

- HH's BC + Government + Market clearing

$$c_1 + \frac{c_2}{1+r} = y_1 + \frac{y_2}{1+r} - \left[1 - \frac{1+i^\star}{1+r}\right](F+f)$$

- Last term represents potential losses that CB and HH incur from investing in foreign assets when $r > i^\star$ ([IP] holds as strict inequality)

- HH's optimality: $\left[1 - \frac{1+i^\star}{1+r}\right] f = 0$

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Non-monetary economy

$$\max_{c_1, c_2} u(c_1) + \beta u(c_2)$$

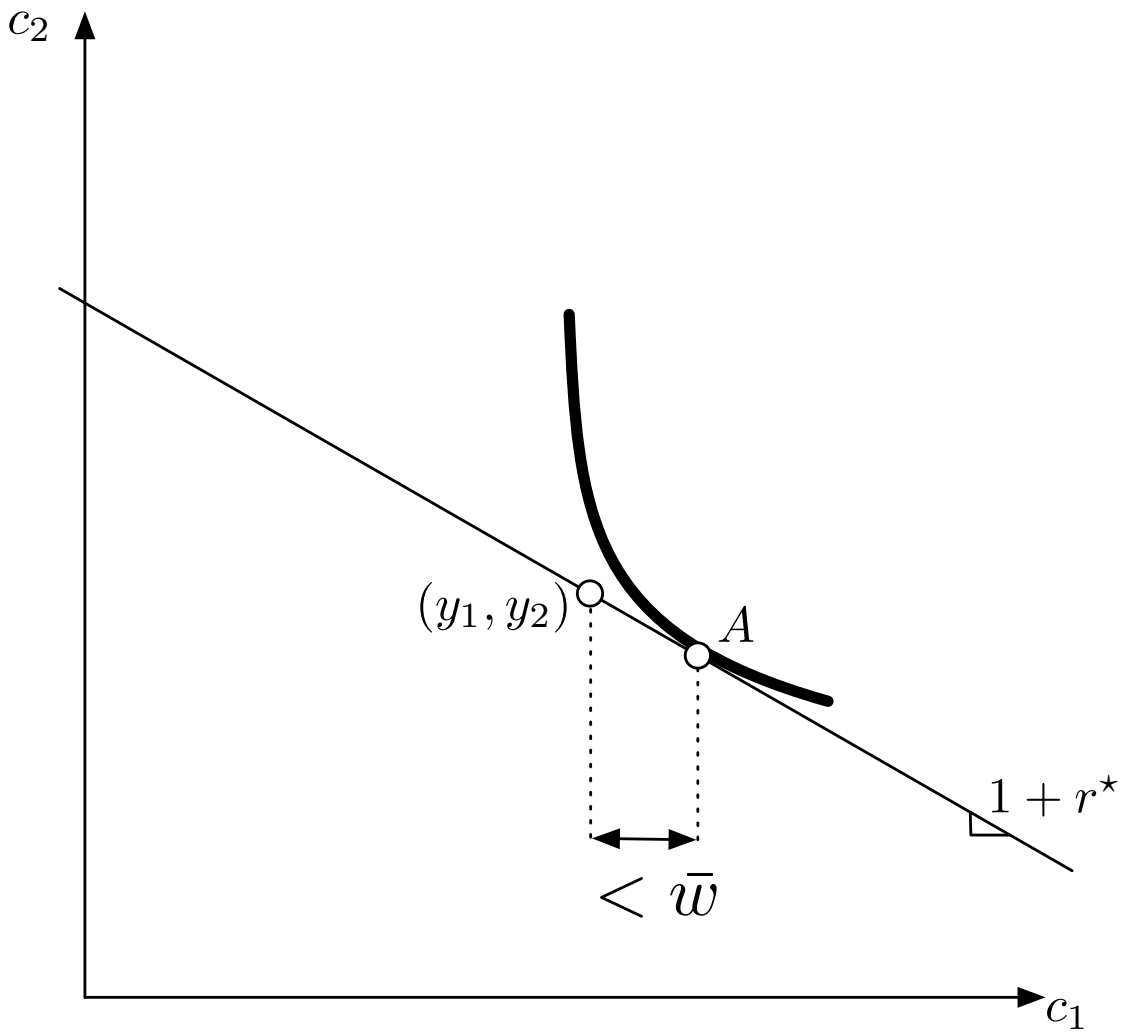
subject to:

$$\underbrace{c_1 + \frac{c_2}{1+r}}_{\text{PV of consumption}} = \underbrace{y_1 + \frac{y_2}{1+r}}_{\text{PV of endowment}} - \underbrace{\left[1 - \frac{1+i^*}{1+r}\right] F}_{\text{Intervention loss}}$$

$$c_1 \leq y_1 - F + \bar{w}$$

- Accumulation of foreign assets by the CB has two potential effects
  - It can lead to a wedge between r and $i^\star$
  - But generates a loss for the small open economy, $\left[1 - \frac{1+i^*}{1+r}\right] F$

The Effects of CB Interventions



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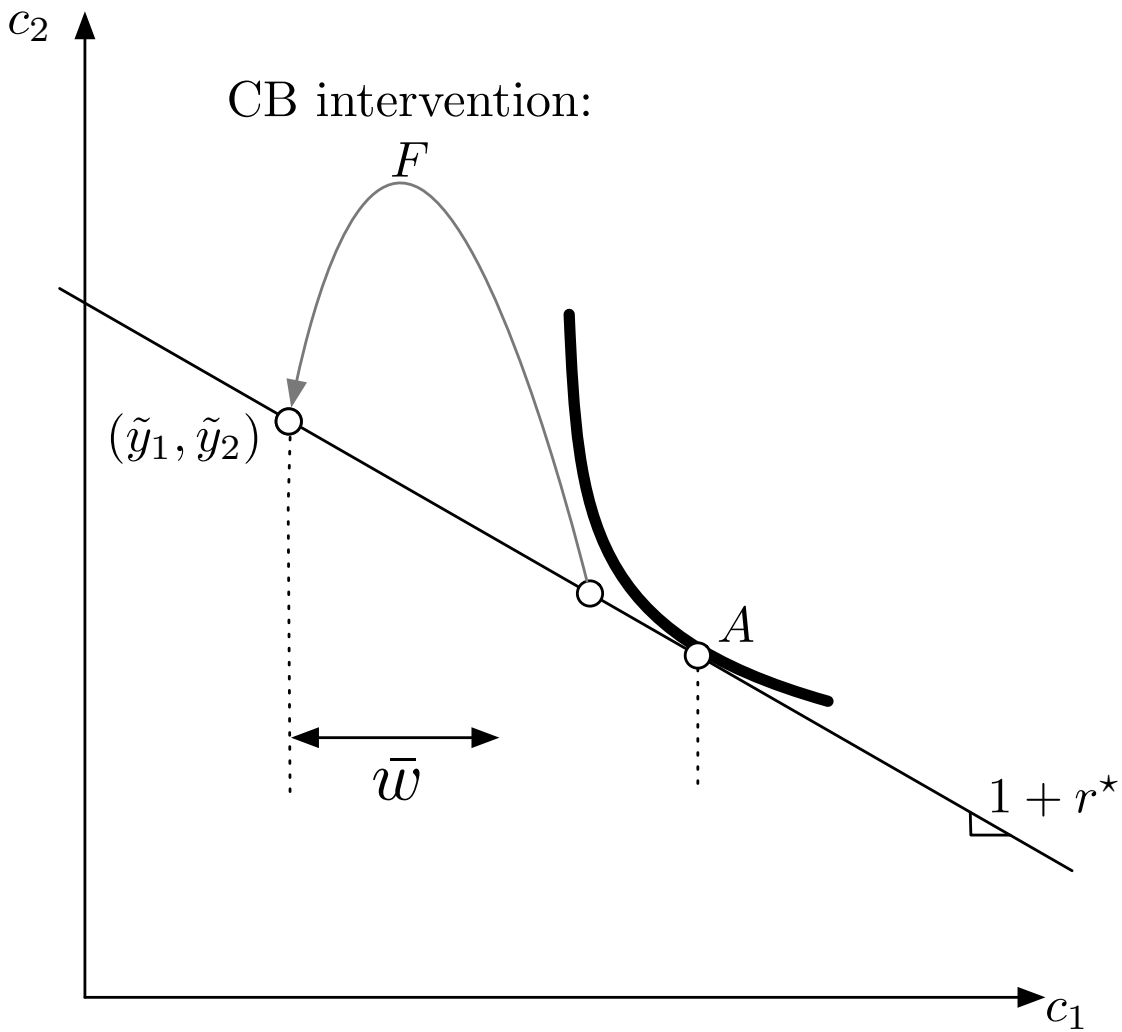

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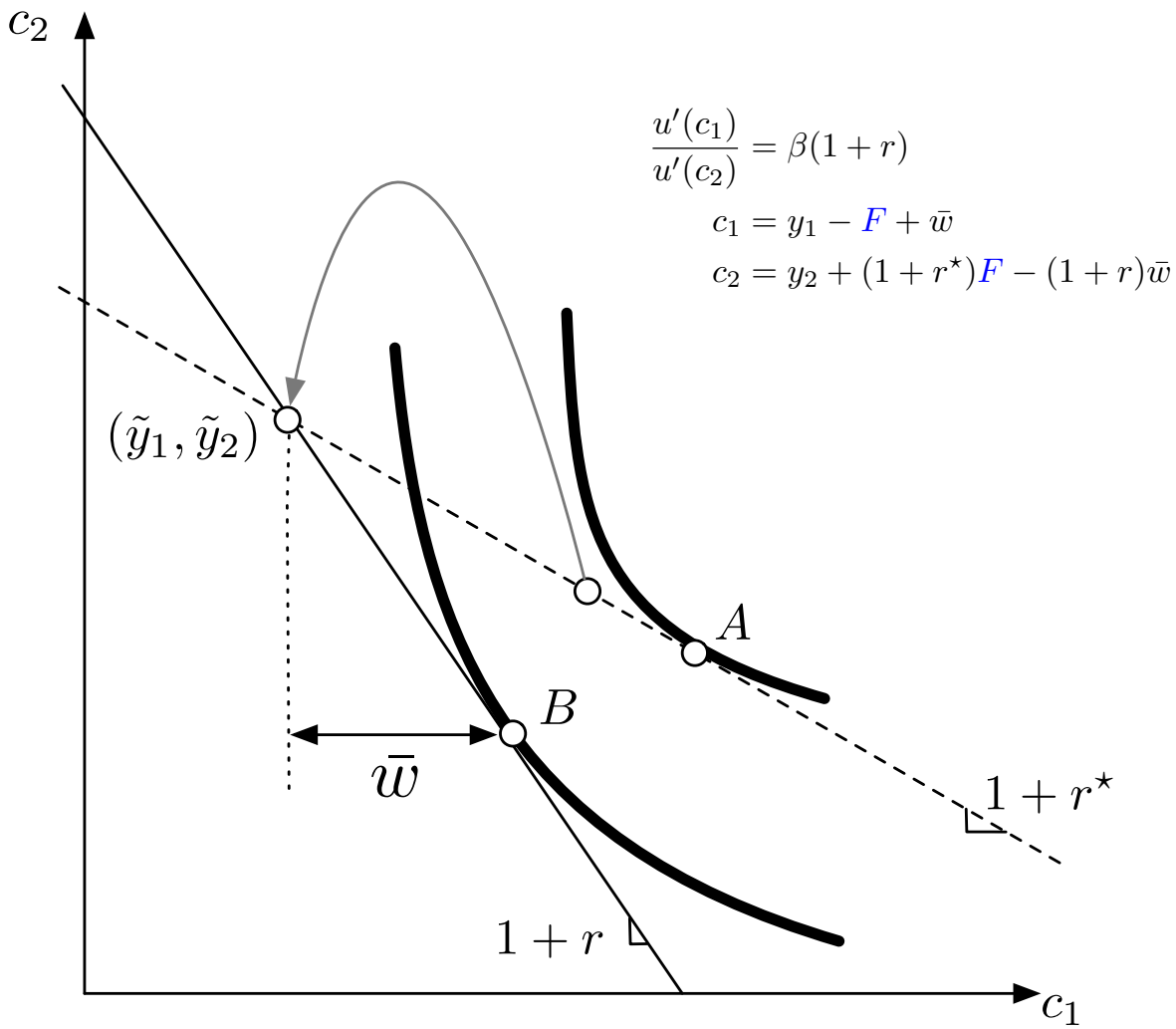

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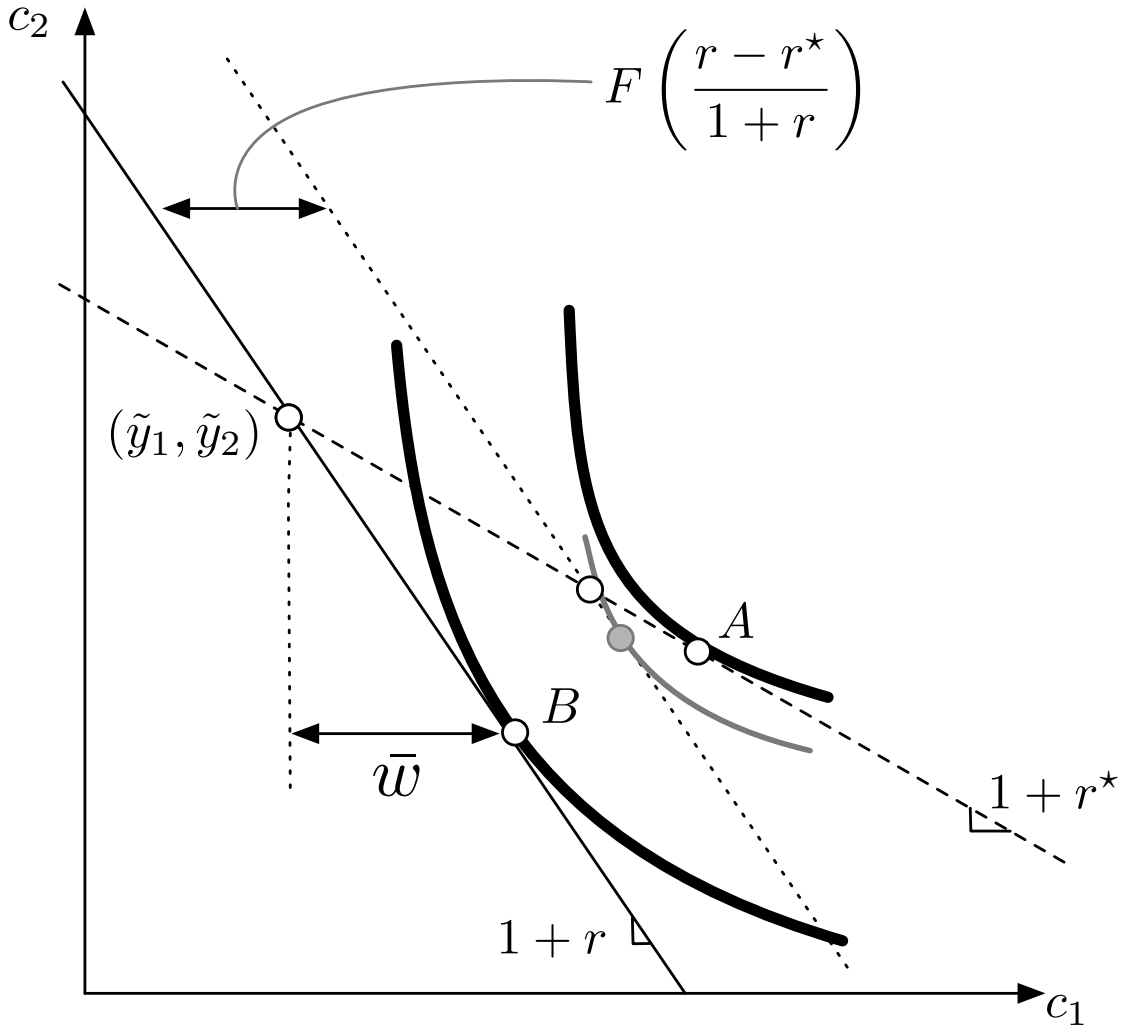

Taking Stock

- If $\bar{w}$ large enough, intervention is neutral
  - HH's undo the effect by borrowing
- If $\bar{w}$ not large enough, interventions allow the CB to sustain $r > i^\star$
  - When $r > i^\star$, foreign wealth comes in
  - CB forced to reverse the trade made by foreigners
  - CB incurs losses to sustain $r > i^\star$ (opposite side of arbitrage profits)
- Household welfare is decreasing in F. Best non-monetary equilibrium is the one where $F = 0$
  - Let $\underline{r} \geq i^\star$ be domestic rate in this equilibrium
- Why would the CB set $F > 0$? Let's go back to the monetary economy...

Monetary economy: Away from ZLB

Suppose $(1+\underline{r})\frac{s_2}{s_1} > 1$. Then

- Any non-monetary eqm for $F \geq 0$ constitutes a monetary eqm outcome
- Best monetary eqm outcome is $F = 0$
- CB can implement (s_1, s_2) by setting the nominal interest rate

$$(1+\underline{r})\frac{s_2}{s_1} > 1,$$

  and $F = 0$

- If $\underline{r} = i^\star$, then [IP] holds with equality
  - Foreign exchange interventions locally irrelevant

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Monetary economy: At the ZLB

Suppose $(1+\underline{r})\frac{s_2}{s_1} < 1$. Then

- Non-monetary eqm with $F = 0$ is not a monetary outcome
  - Given exchange rate policy $\Rightarrow$ i would have to be negative
- Best monetary eqm outcome has $F = \underline{F} > 0$, $i = 0$, and [IP] holding with strict inequality
- CB can implement (s_1, s_2) by setting $i = 0$ and $F = \underline{F}$
- Because [IP] holds with inequality, foreign wealth comes in
  - Accumulation of foreign assets allows the CB to sustain (s_1, s_2)

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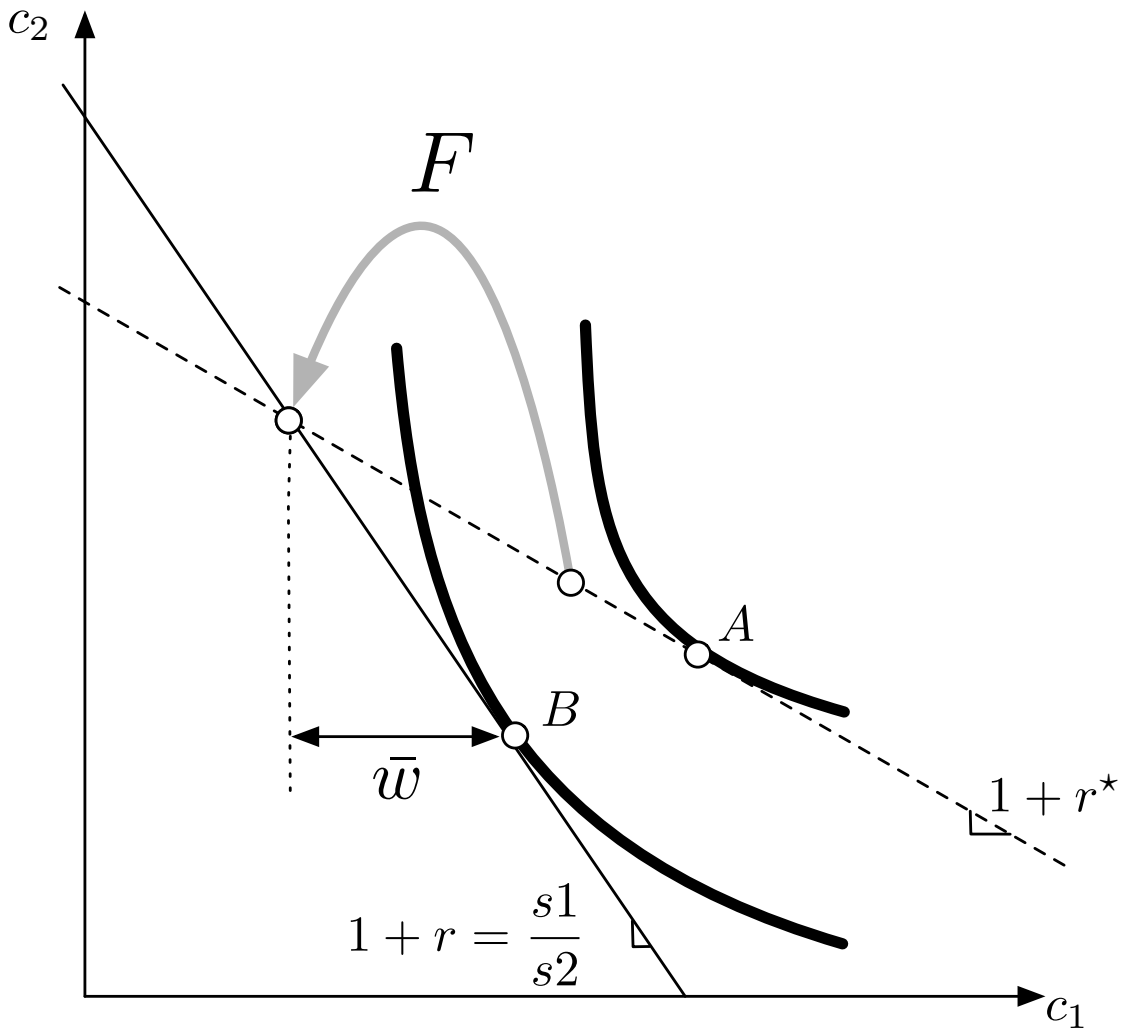


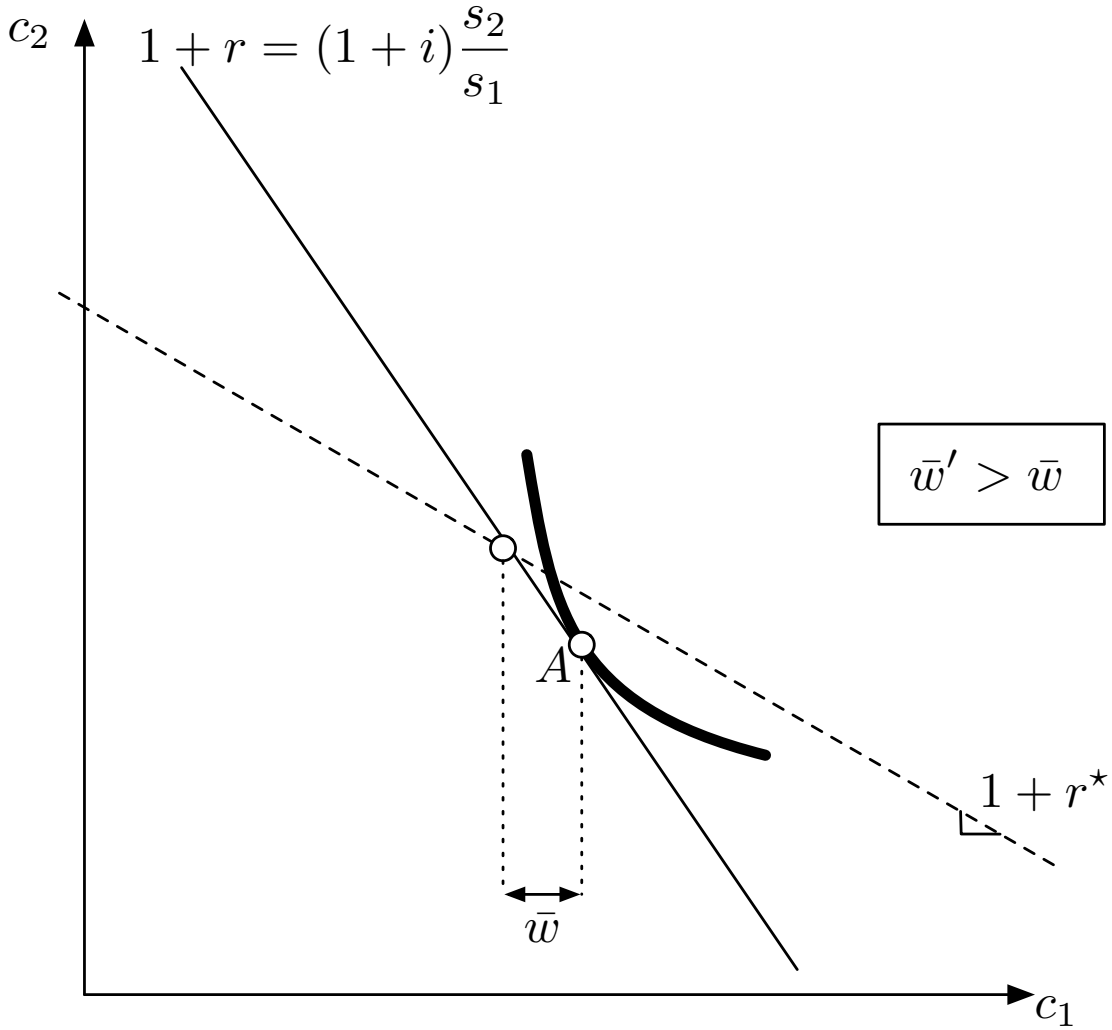
Capital Inflows and the Costs of FX Interventions

Comparative Statics

- Central Bank can sustain a depreciated exchange rate at the ZLB by accumulating foreign assets. These unconventional interventions are costly for the Central Bank

- Factors that increase the potential for capital inflows raise the necessity of FX interventions, and increase their costs
  - More foreign wealth, $\bar{w}$
  - Lower international rates, $i^{\star}$
  - Irrational expectations of appreciation of domestic currency

Higher $\bar{w}$: Away from ZLB



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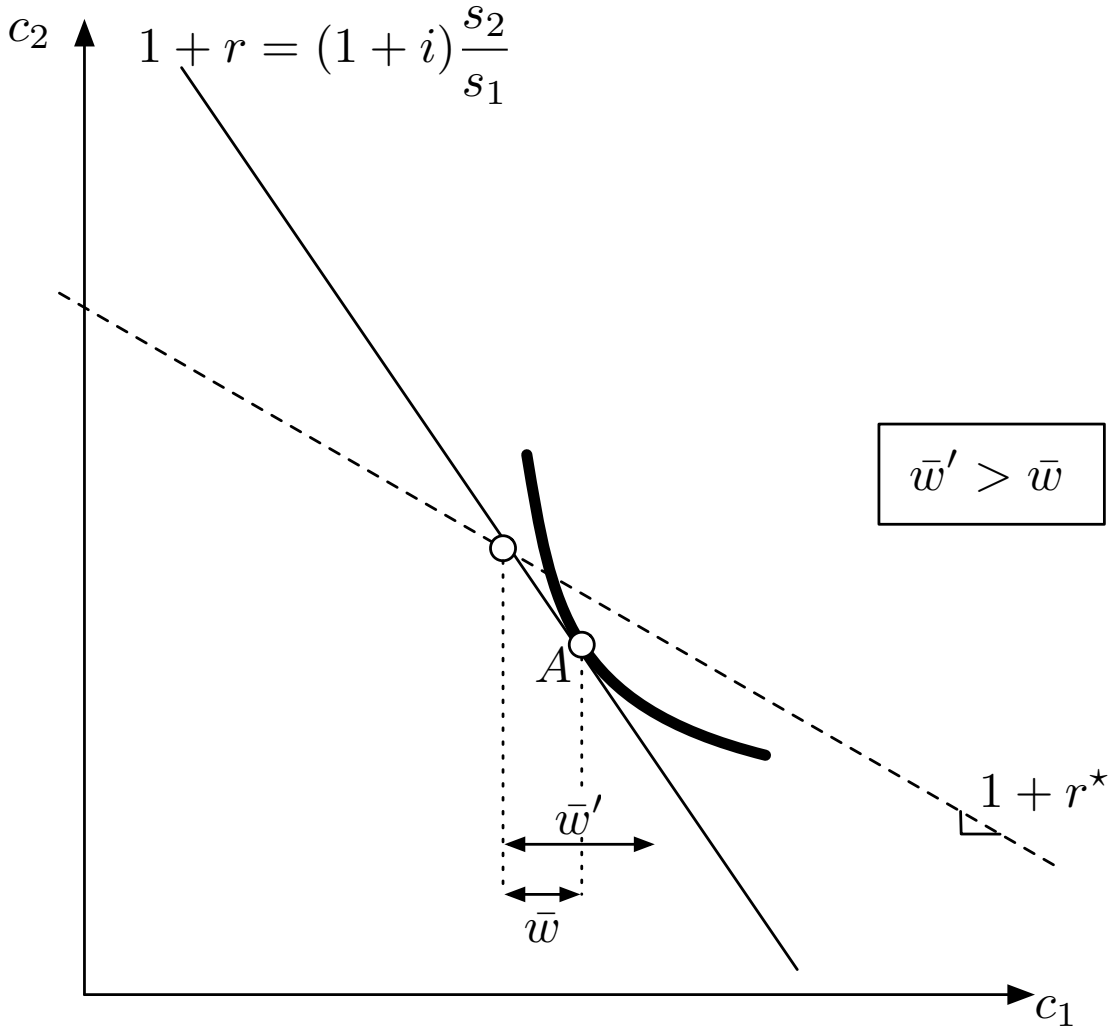

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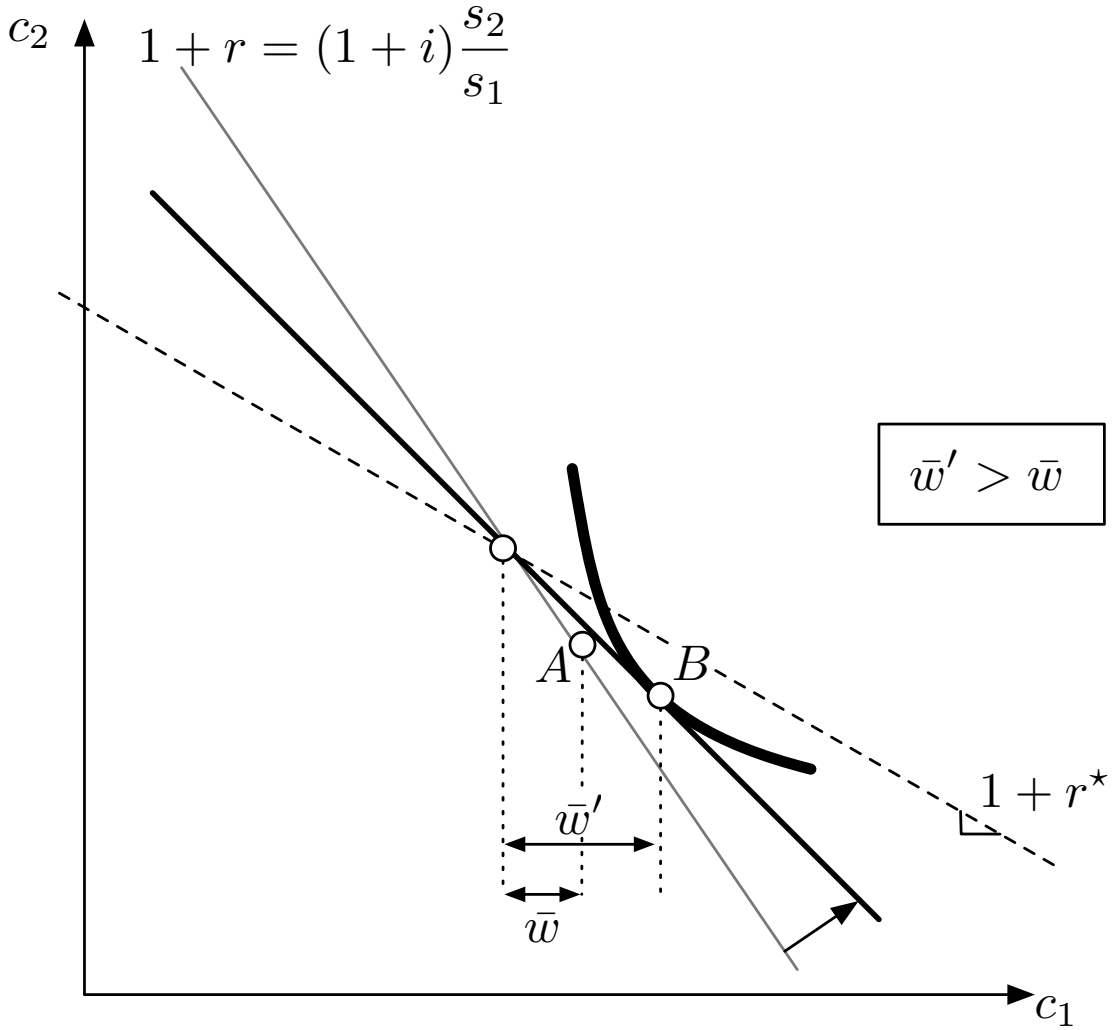

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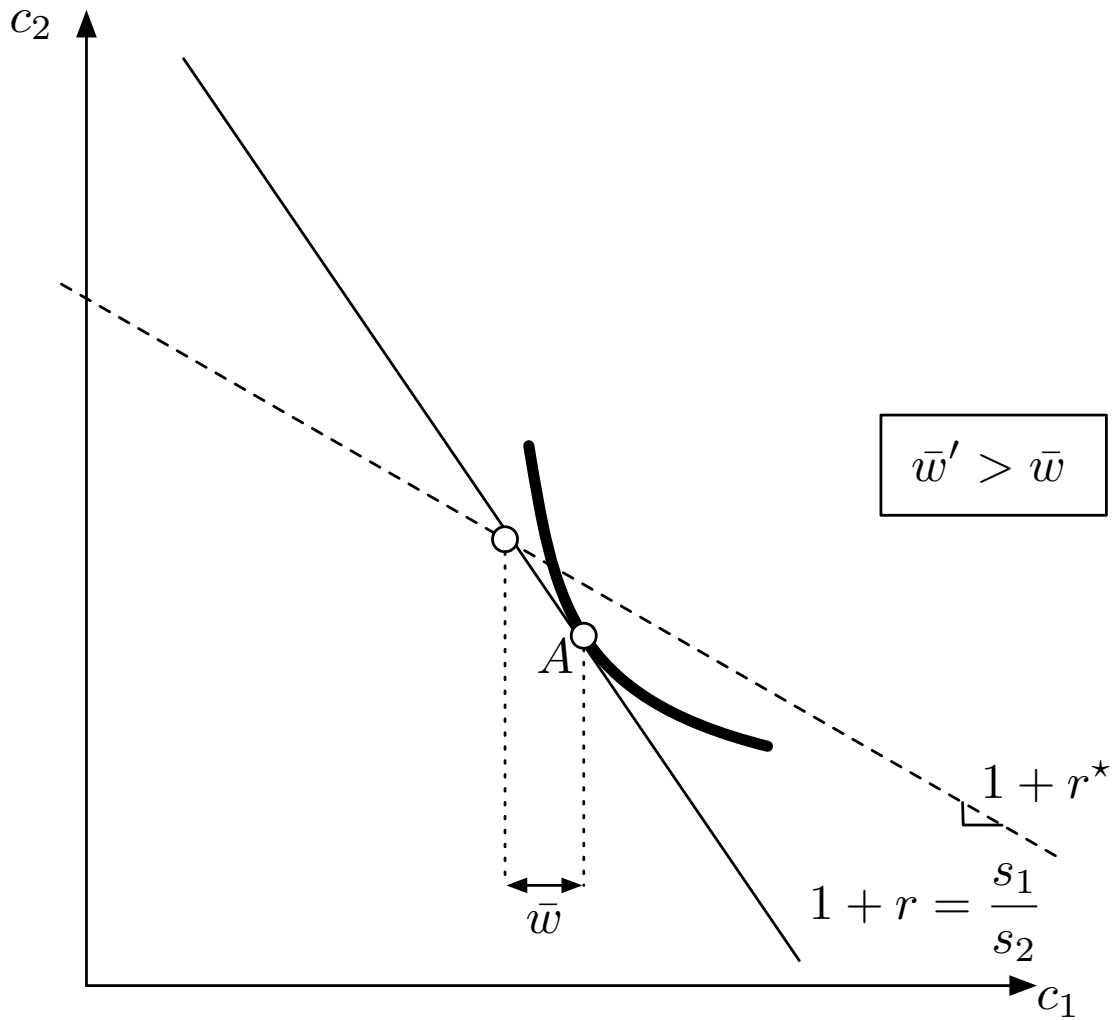

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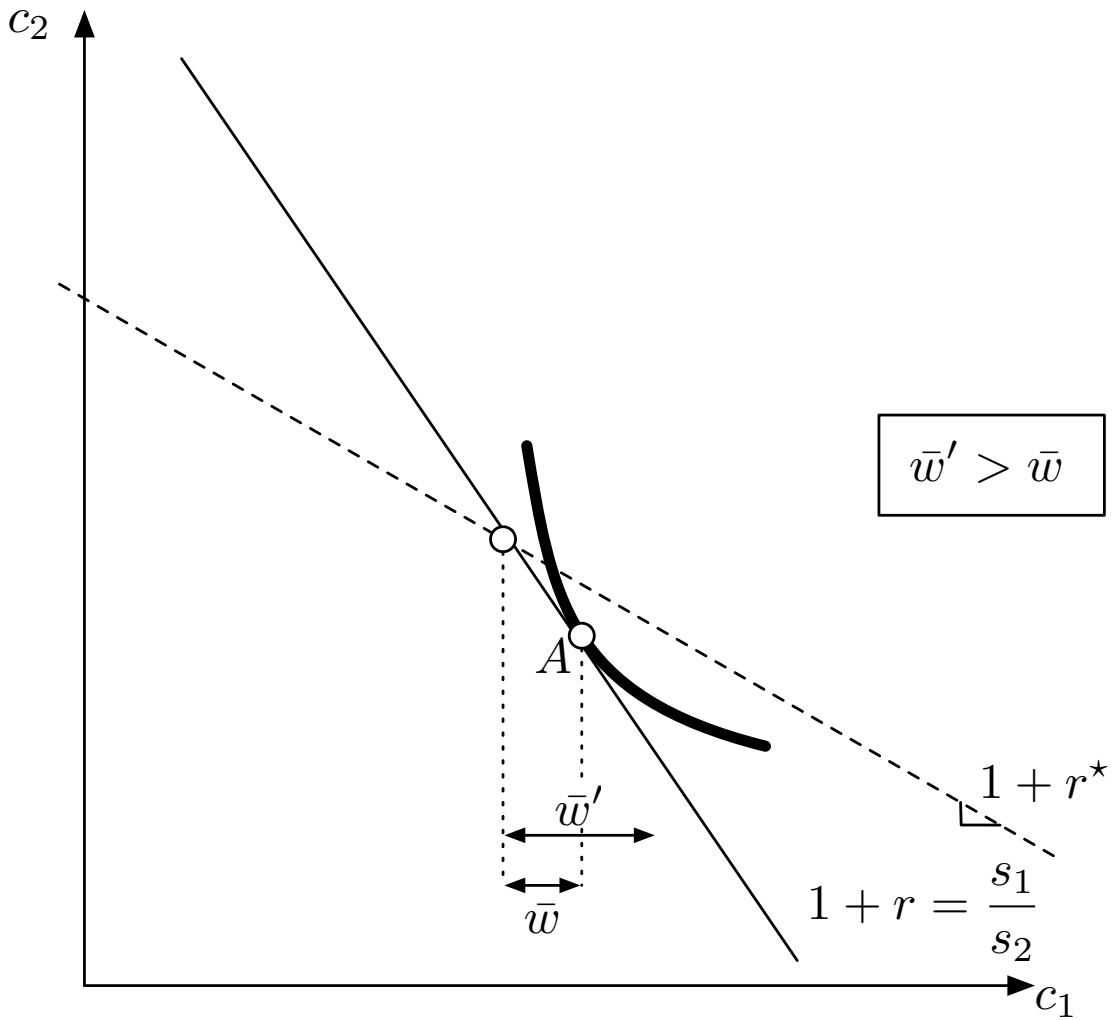

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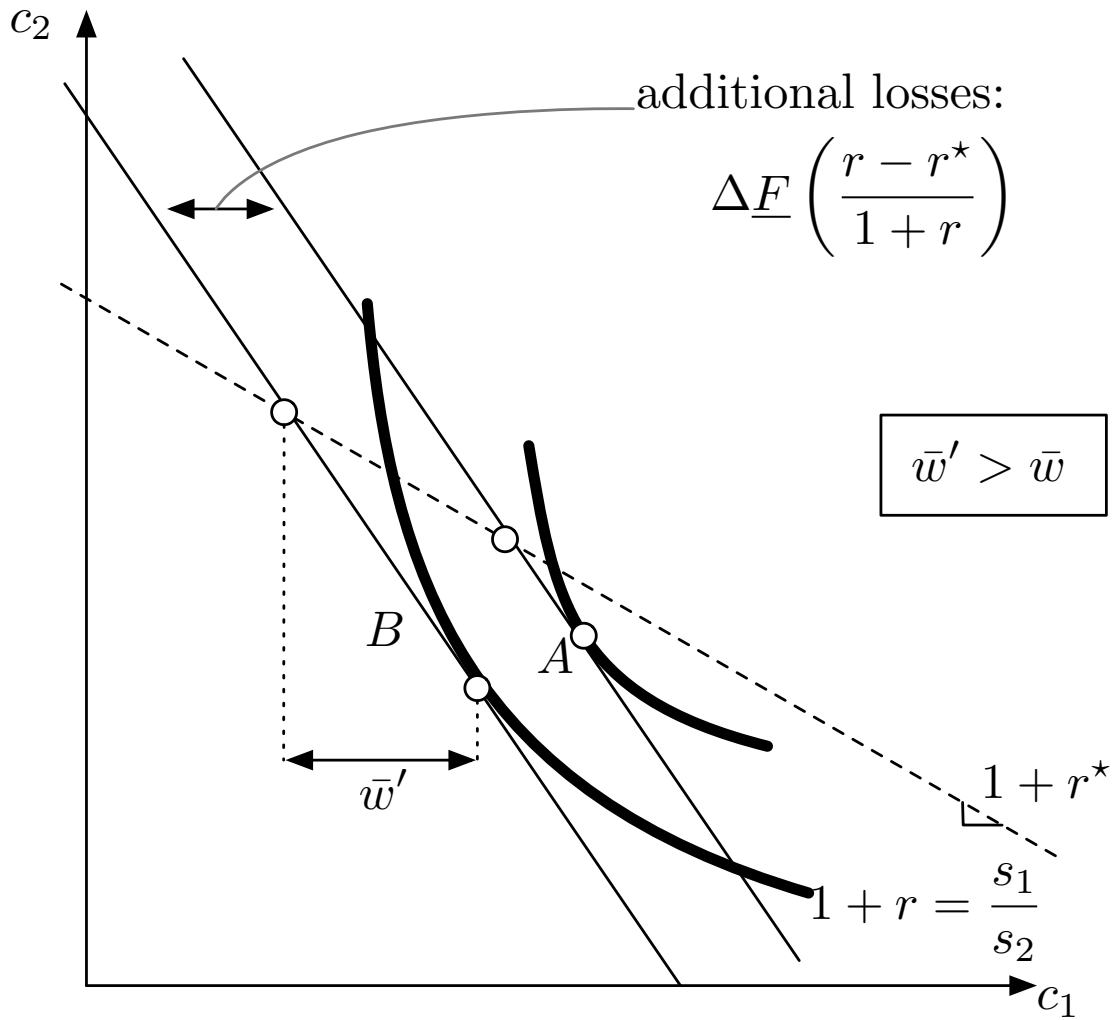

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- Factors that increase the potential for capital inflows raise the necessity of FX interventions, and increase their costs
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  - Lower international rates, $i^\star$
  - Irrational expectations of appreciation of domestic currency

- Policies hindering inflows (capital controls, negative nominal rates) reduce the necessity for these interventions, and reduce their costs

Alternative policy instruments

- **Capital controls**
  - Quantity: lower $\overline{w}$ improves welfare
    - Optimal $\bar{w}$ implies $F = 0$
  - Prices: taxes on foreign purchases of domestic assets
    - Optimal tax implies [IP] holds with equality
    - Note: At the ZLB need to tax foreign holdings of money
- **Negative nominal interest rates**
  - Allow the CB to restore interest parity and avoid expansion of balance sheet
- Complements or substitutes?
  - With exogenous (s_1, s_2), additional instruments substitute FX interventions
  - With endogenous (s_1, s_2), policy instruments may complement each other

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Optimal Exchange Rate Policies

A simple sticky-wage model

- Two sectors, producing tradable (T) and non-tradable (NT) goods
- Output in sector j produced with Cobb-Douglas,

$$y_t^j = (l_t^j)^\alpha$$

- Nominal wages are fixed in domestic currency, and constant over time $\bar{p}^w$
- Firms in both sectors maximize profits

$$\Pi_t^j = \max_{l_t^j} p_t^j y_t - \frac{\bar{p}^w}{s_t} l_t^j$$

- Firms' FOC:

$$l_t^N = \left(\frac{\alpha p_t^N s_t}{\bar{p}^w}\right)^{\frac{1}{1-\alpha}} \qquad l_t^T = \left(\frac{\alpha s_t}{\bar{p}^w}\right)^{\frac{1}{1-\alpha}}$$

The problem of the Central Bank

- The Central Bank chooses (i, s_1, s_2, F) to maximize HH's welfare taking as given optimality of HH's, firms, and foreign investors
- Let $\overline{p}_t^{w,\text{fb}}$ be the real wage that achieves the first best level of production,

$$v'(n_t) = u'_{T,t} f'(l_t^T) \qquad v'(n_t) = u'_{N,t} f'(l_t^N)$$

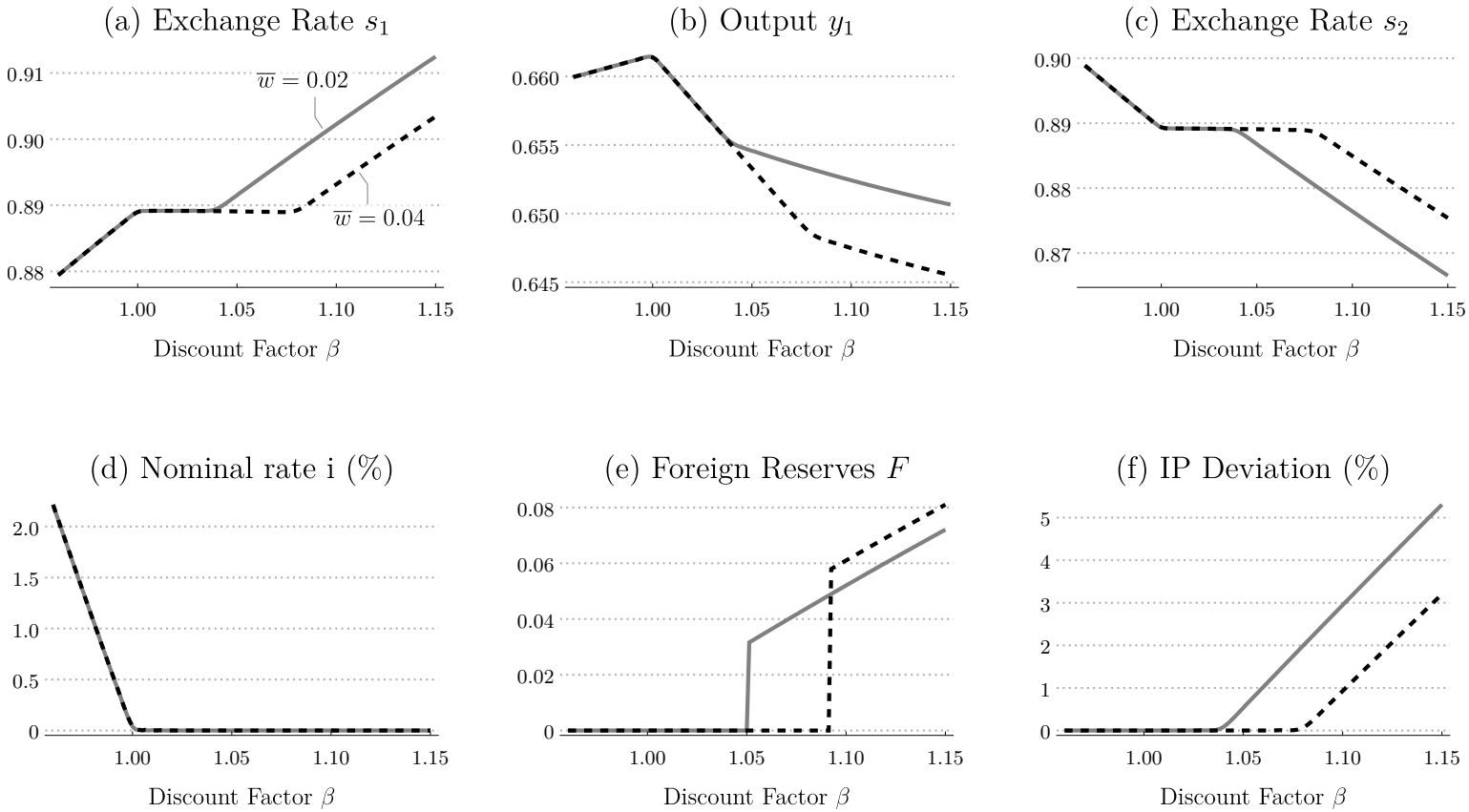
- The Central Bank has incentives to choose (s_1, s_2) to achieve first best
  - Depreciate when output inefficiently low
  - Appreciate when output inefficiently high

Central Bank's solution

- If $(1+i^\star)\frac{s_2^{fb}}{s_1^{fb}} \geq 1$, then
  - ZLB does not bind
  - Central Bank implements first best output by varying nominal rate

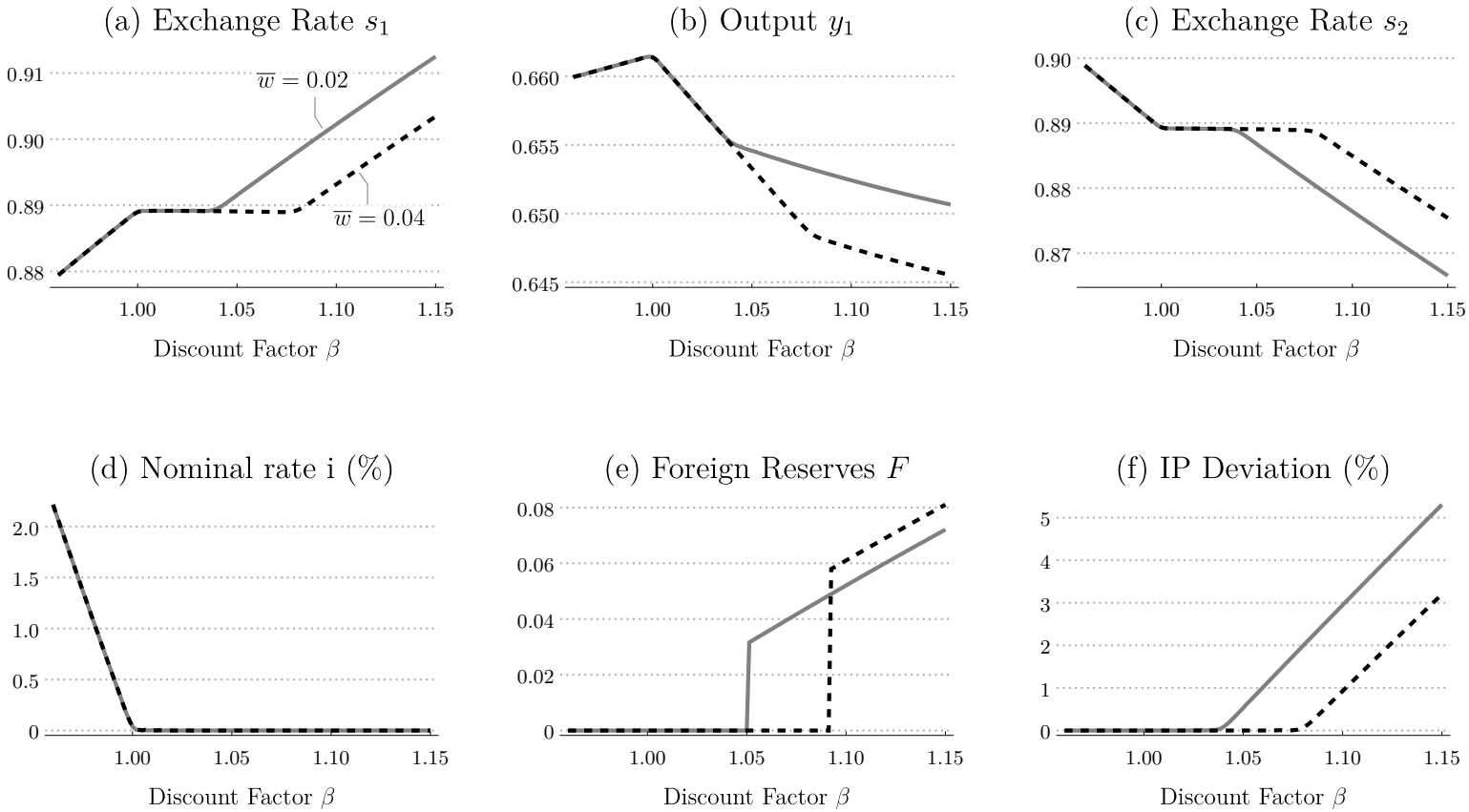
- If $(1+i^\star)\frac{s_2^{fb}}{s_1^{fb}} < 1$, then
  - ZLB binds: depreciating the exchange rate requires CB interventions
  - CB trade-offs losses of production efficiency (second order) with losses from FX interventions (first order)
  - Solution: intervene only when losses of production efficiencies are sufficiently large

Numerical example: Discount factor shock



- An increase in β lowers consumption today relative to tomorrow
- First best requires Central Bank depreciating today relative to tomorrow

Numerical example: Discount factor shock



- Initially, policy achieved with a decline in nominal interest rates
- When nominal rates are at zero, CB uses foreign reserves

Empirical Analysis

Some Implications

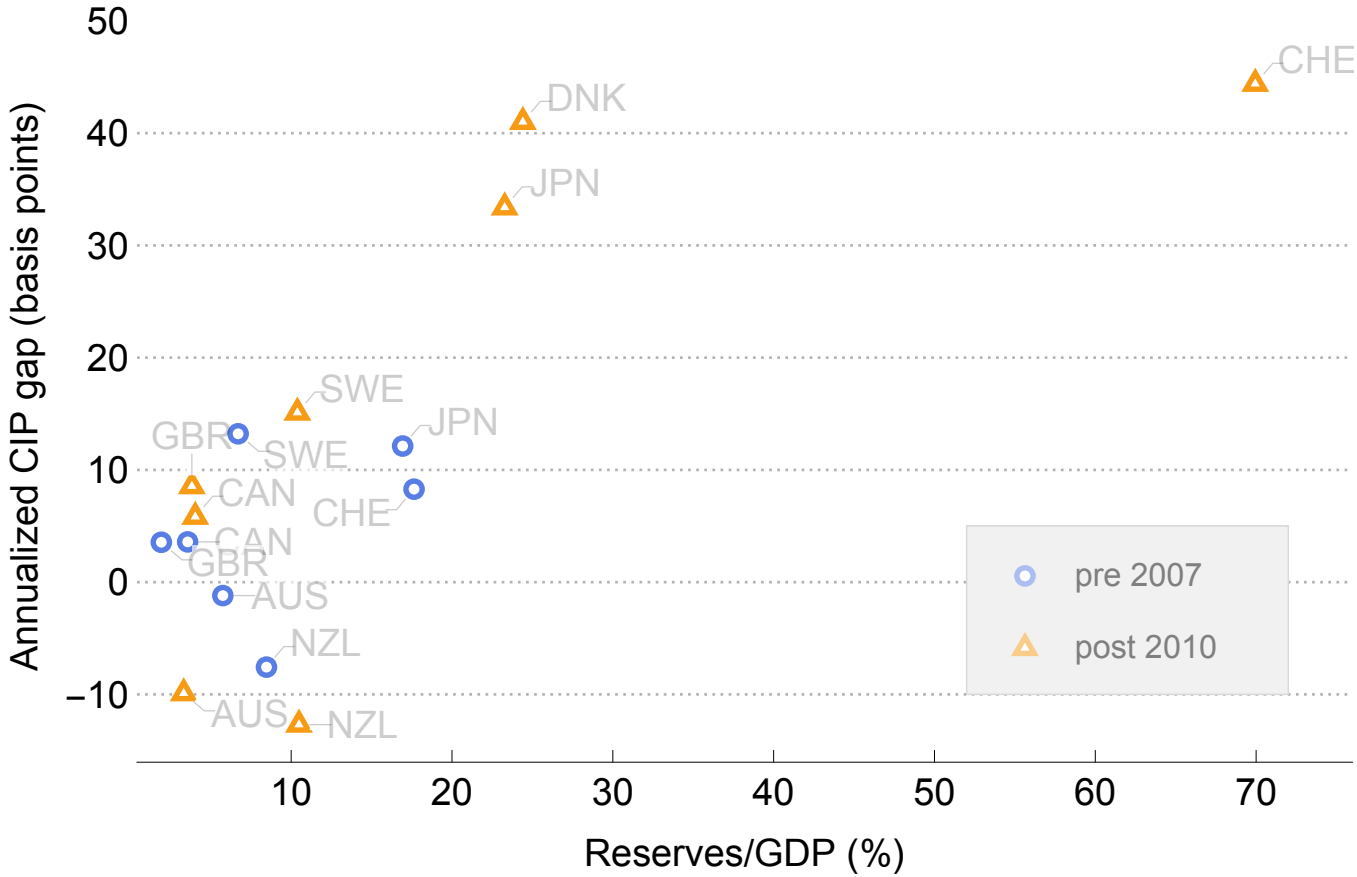
Model has two main implications

1. FX interventions allows a CB to sustain deviations from IP
2. Interventions are necessary at ZLB

Are these predictions consistent with basic facts about foreign reserves, CIP deviations and nominal interest rates?

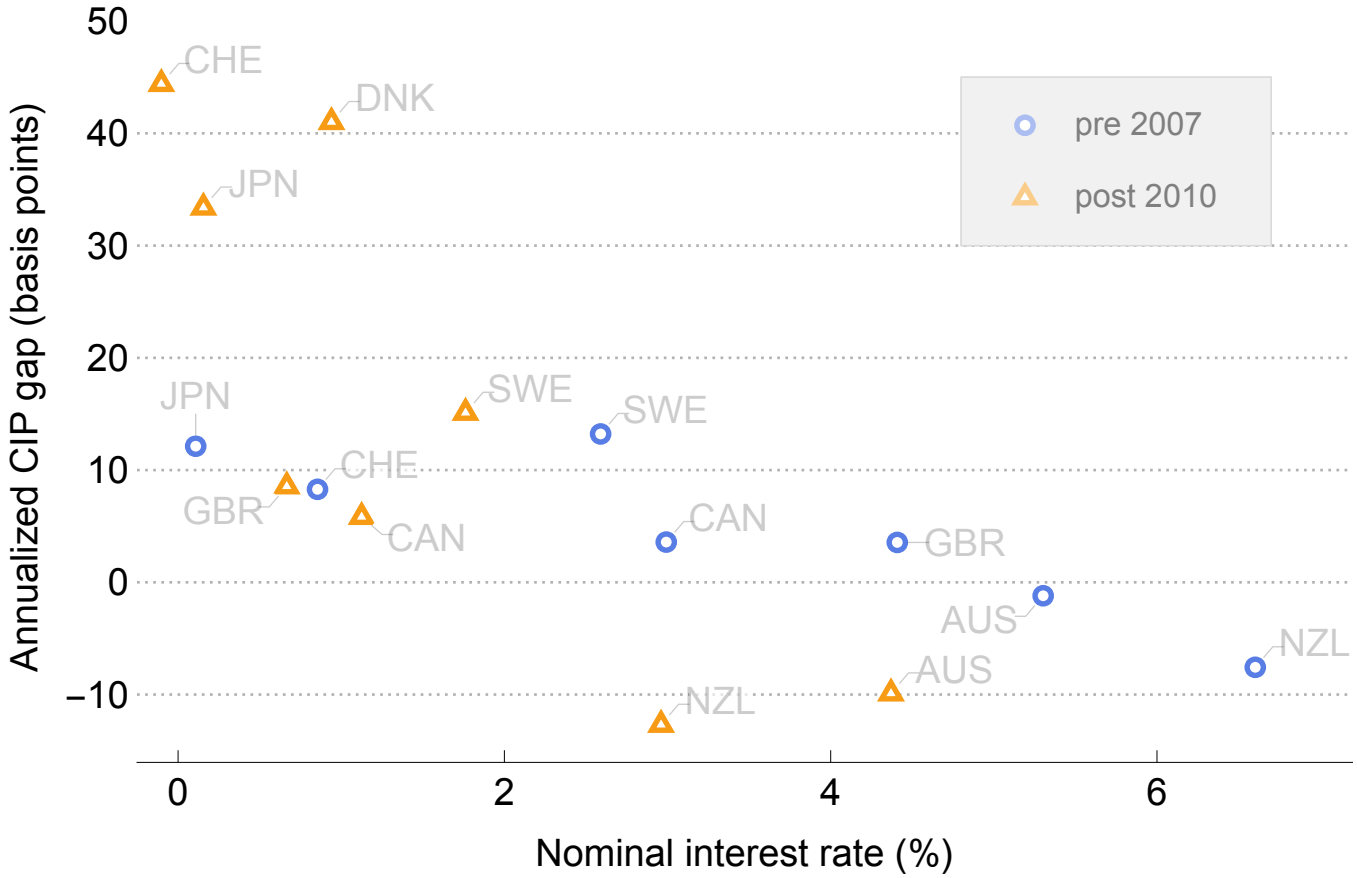
- Cross-section of advanced economies (2000-2016)
- Look at a different ZLB period: Switzerland in the late 1970s

Foreign Reserves and CIP deviations



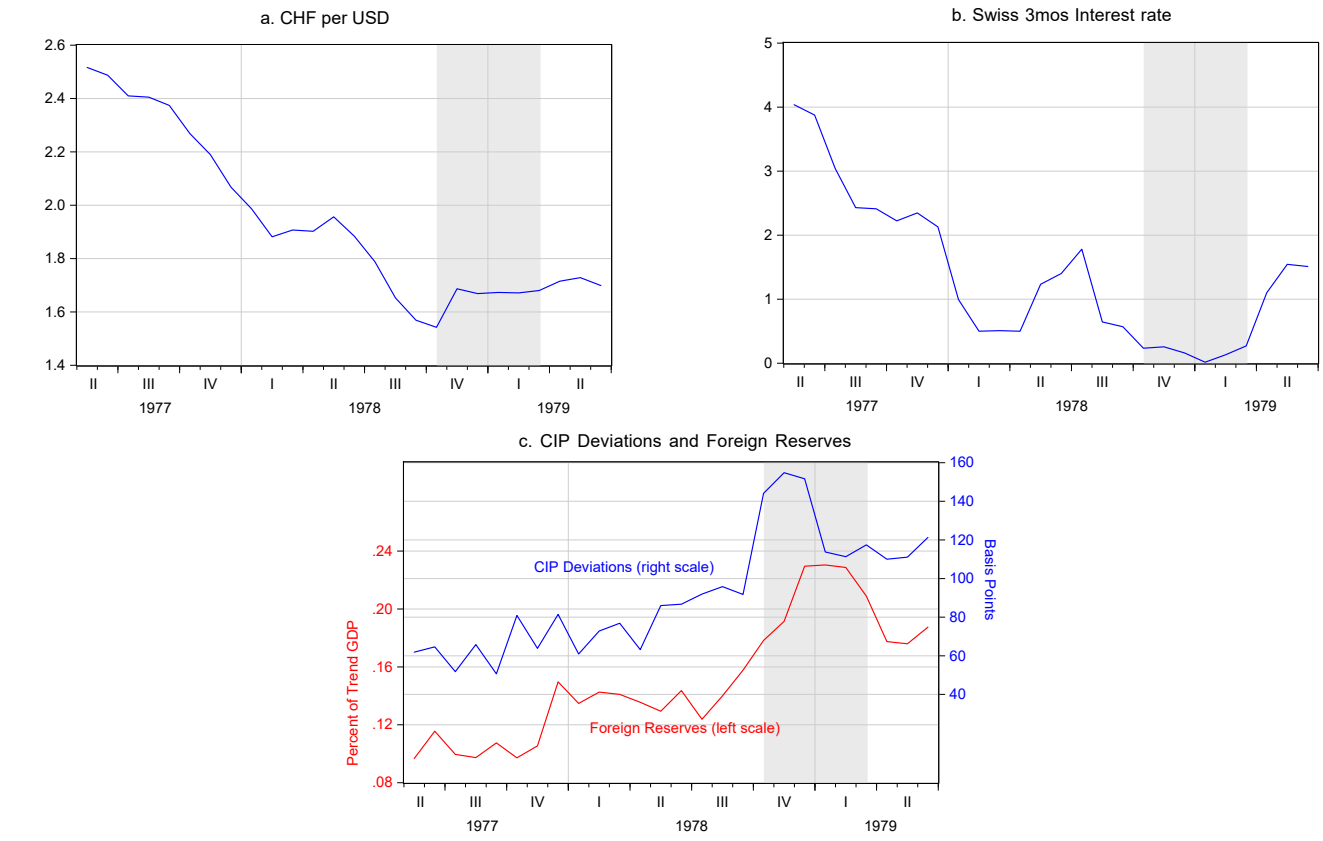
- Positive relation between reserves and CIP gaps
- Relation stronger after 2010
  - Easier to sustain IP deviations with lower $\bar{w}$ (Du et al., 2016)

CIP deviations and Nominal Interest Rates



- Deviations from CIP for countries with rates close to zero

A Different ZLB Period



Note: the shaded areas in all panels represent the months in which the Swiss interest rate was below 0.5%.

- A similar pattern observed for Switzerland in the 1970s

Quantifying the costs of FX Interventions

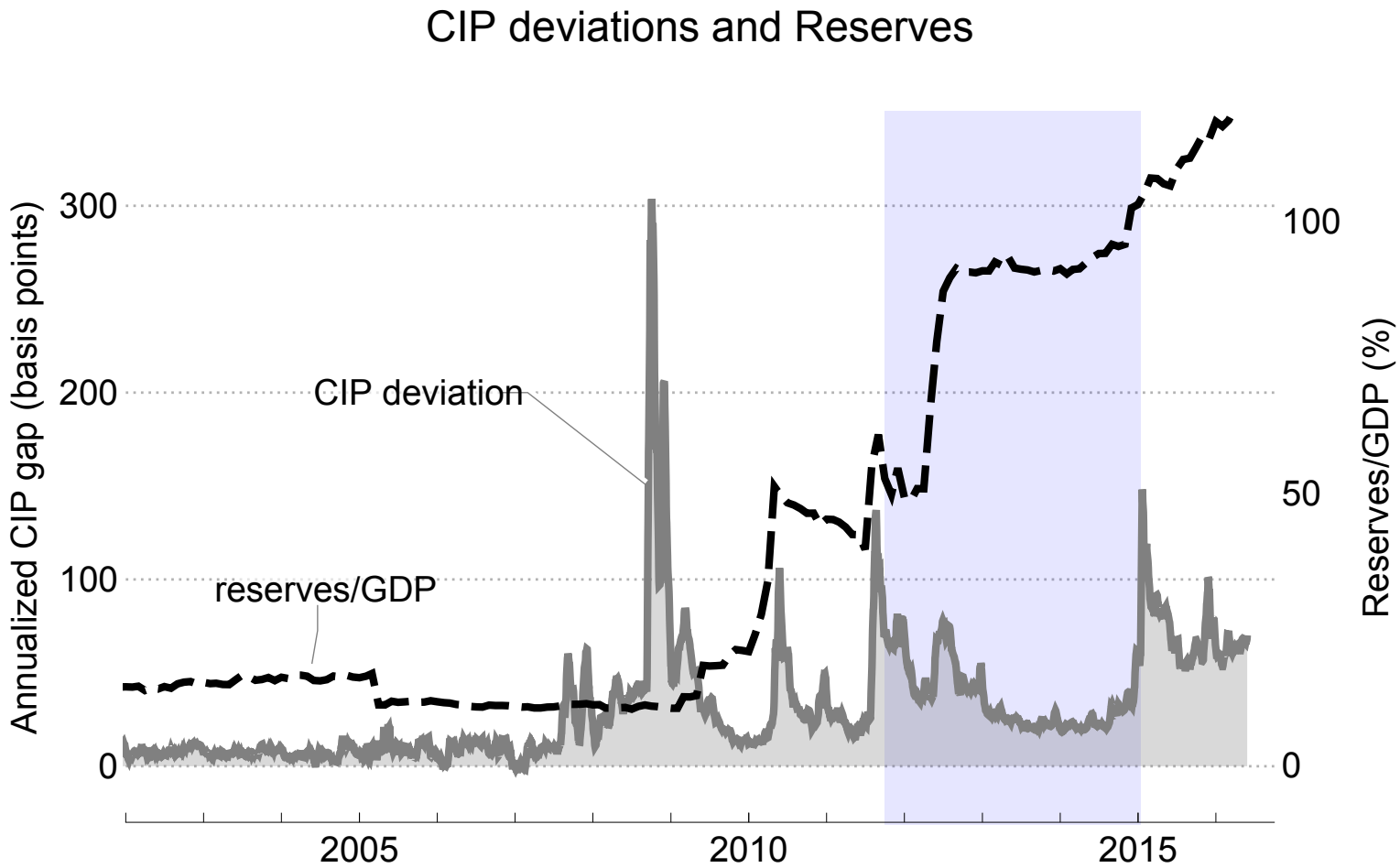
- Losses:

$$\underbrace{\left[1 - \frac{1 + i^{\star}}{1 + i}\frac{s_2}{s_1}\right]}_{\text{IP deviation}} \times \underbrace{F}_{\text{foreign reserves}}$$

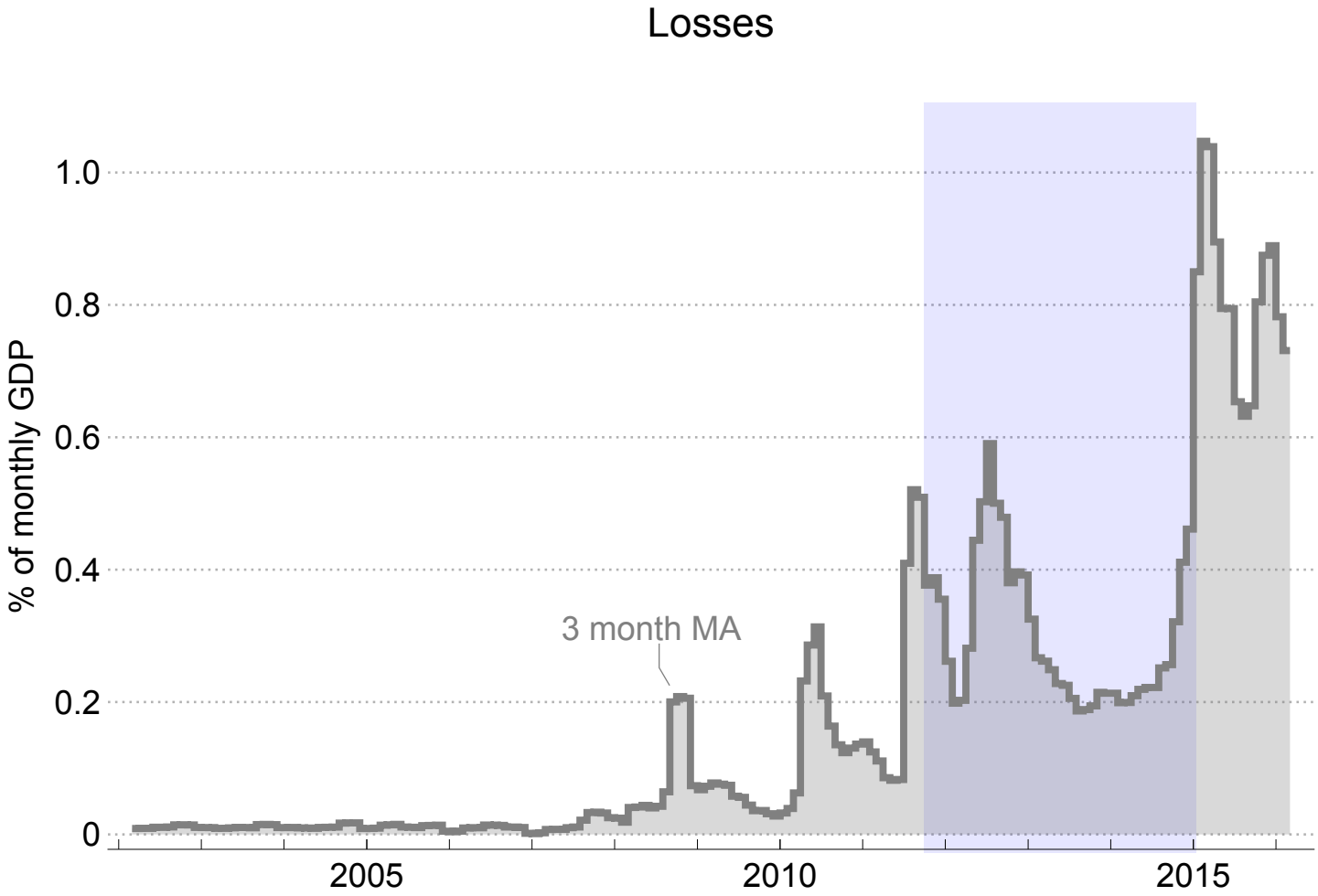
- What is the right measure of the IP deviation?

- Model with uncertainty $\Rightarrow$ Covered Interest Parity

Quantifying the costs of FX Interventions



Quantifying the costs of FX Interventions



- Losses can be sizable (1% of GDP)

Conclusions

- Implementation of exchange rate policies at the ZLB
- Foreign exchange rate interventions are necessary and costly
- Costs increase with factors that stimulate capital inflows
  - Role for capital controls and negative nominal interest rates (Denmark, Sweden, Switzerland)
- Cross-sectional evidence consistent with key mechanisms of the model
- Future work:
  - Optimal reserve management
  - Political economy of “large balance sheets"
  - Self-fulfilling appreciation runs

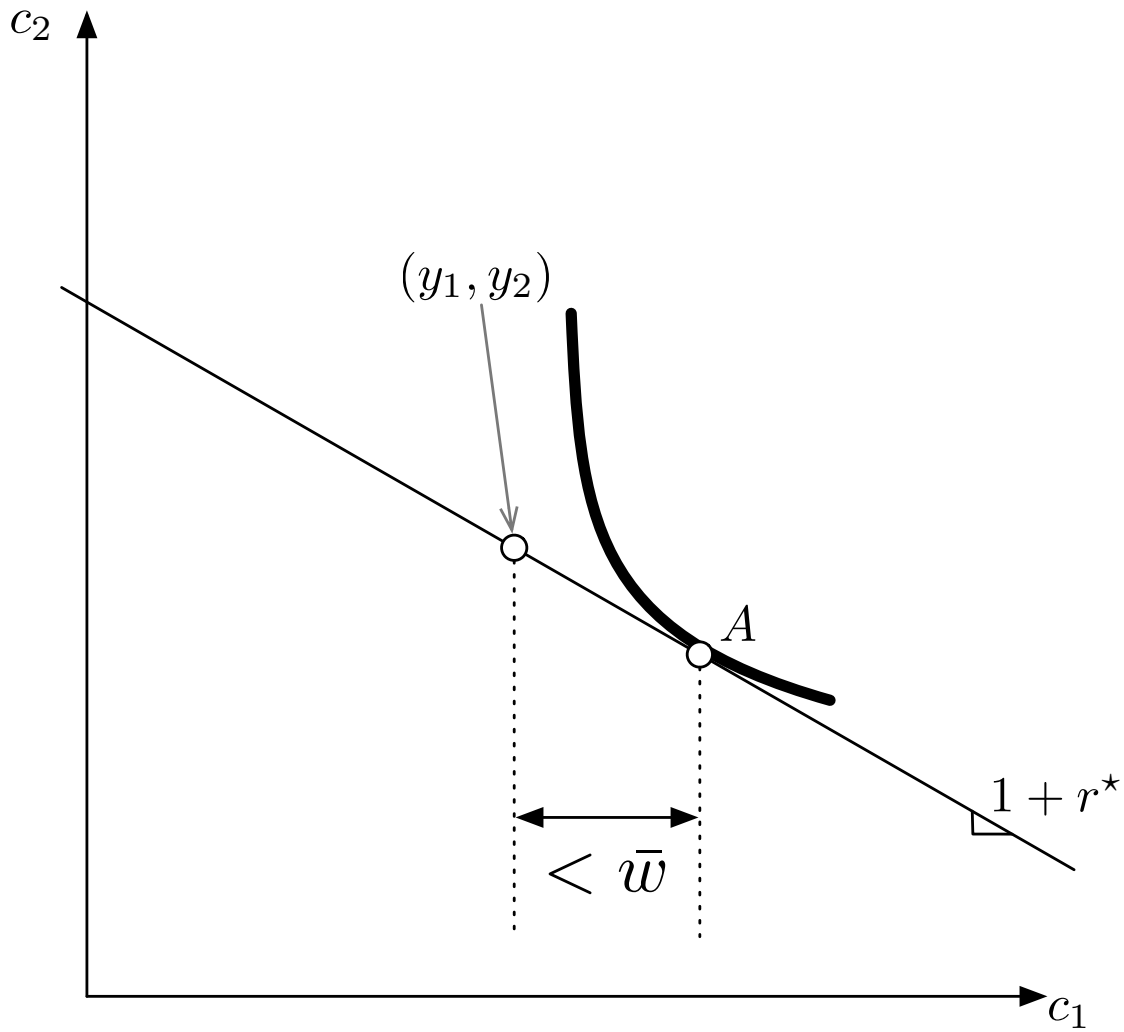
Supplementary Material

Irrational expectations of future appreciation

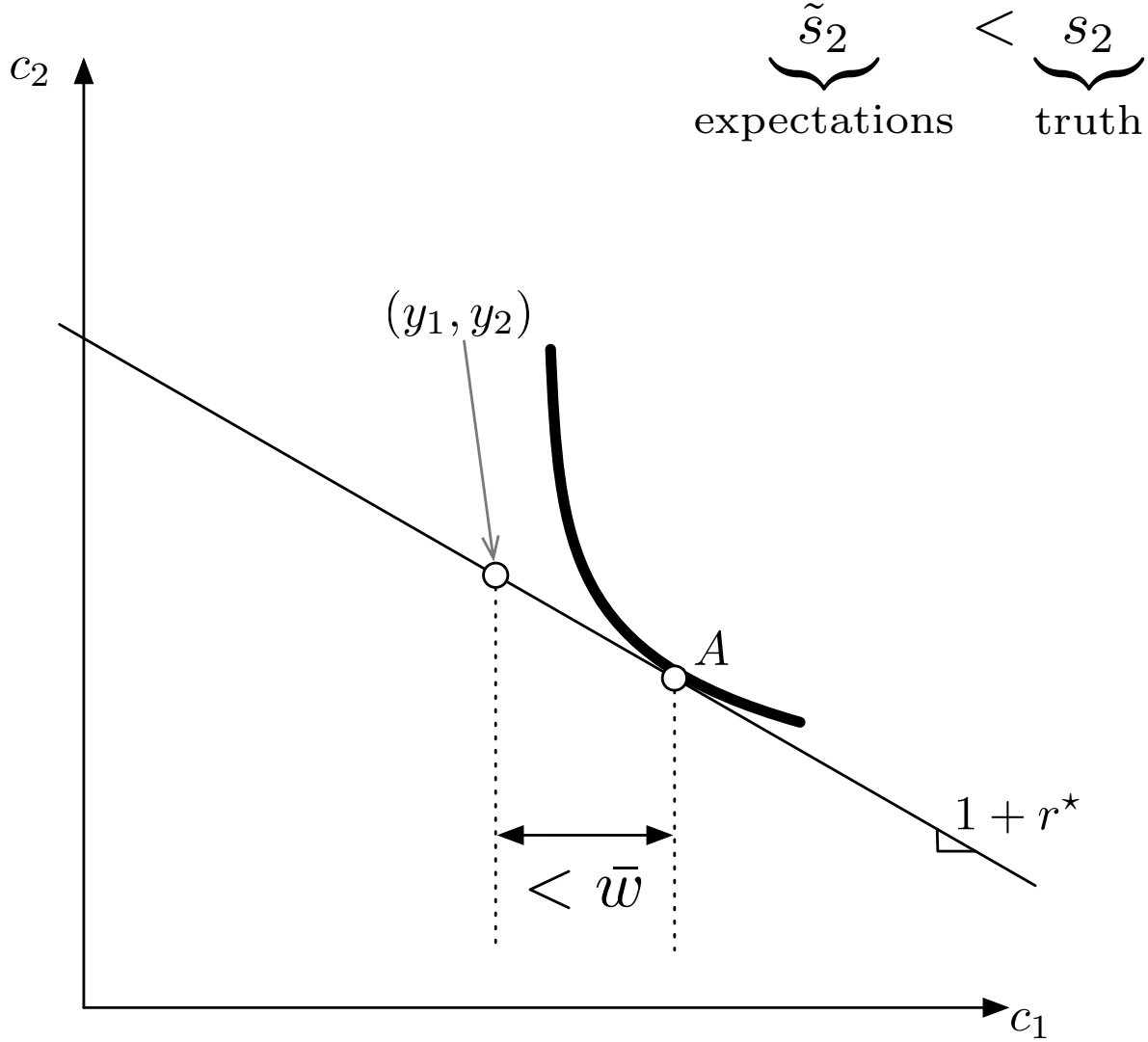
What if markets expect more appreciation relative to actual policy, $\hat{s}_2 < s_2$?

- If ZLB constraint slacks
  - This is good news
  - CB can exploit mistakes of investors and increase HH welfare
- If ZLB constraint binds
  - This is bad news
  - CB cannot exploit the mistakes and needs to accumulate foreign assets

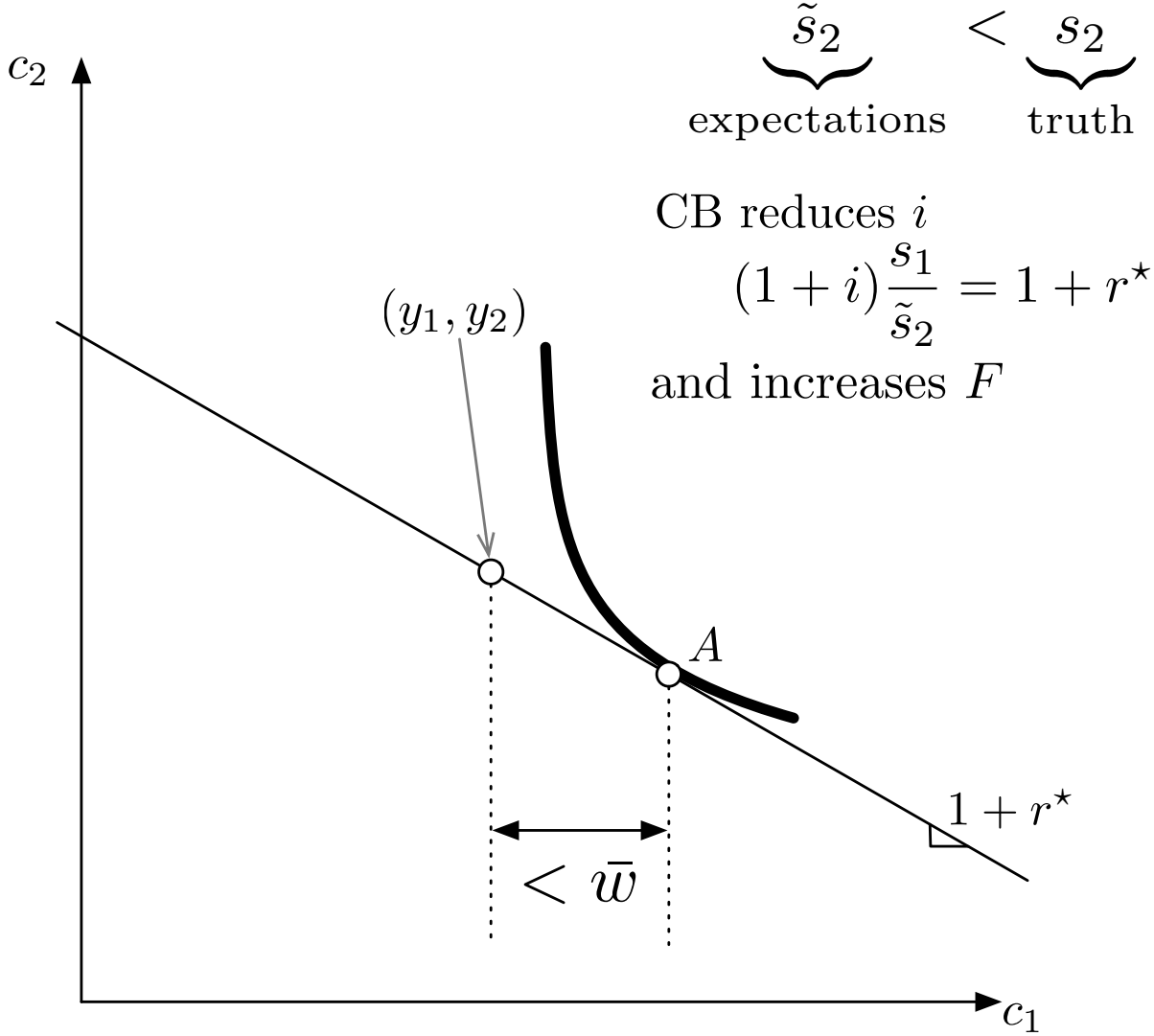
Irrational expectations away from ZLB



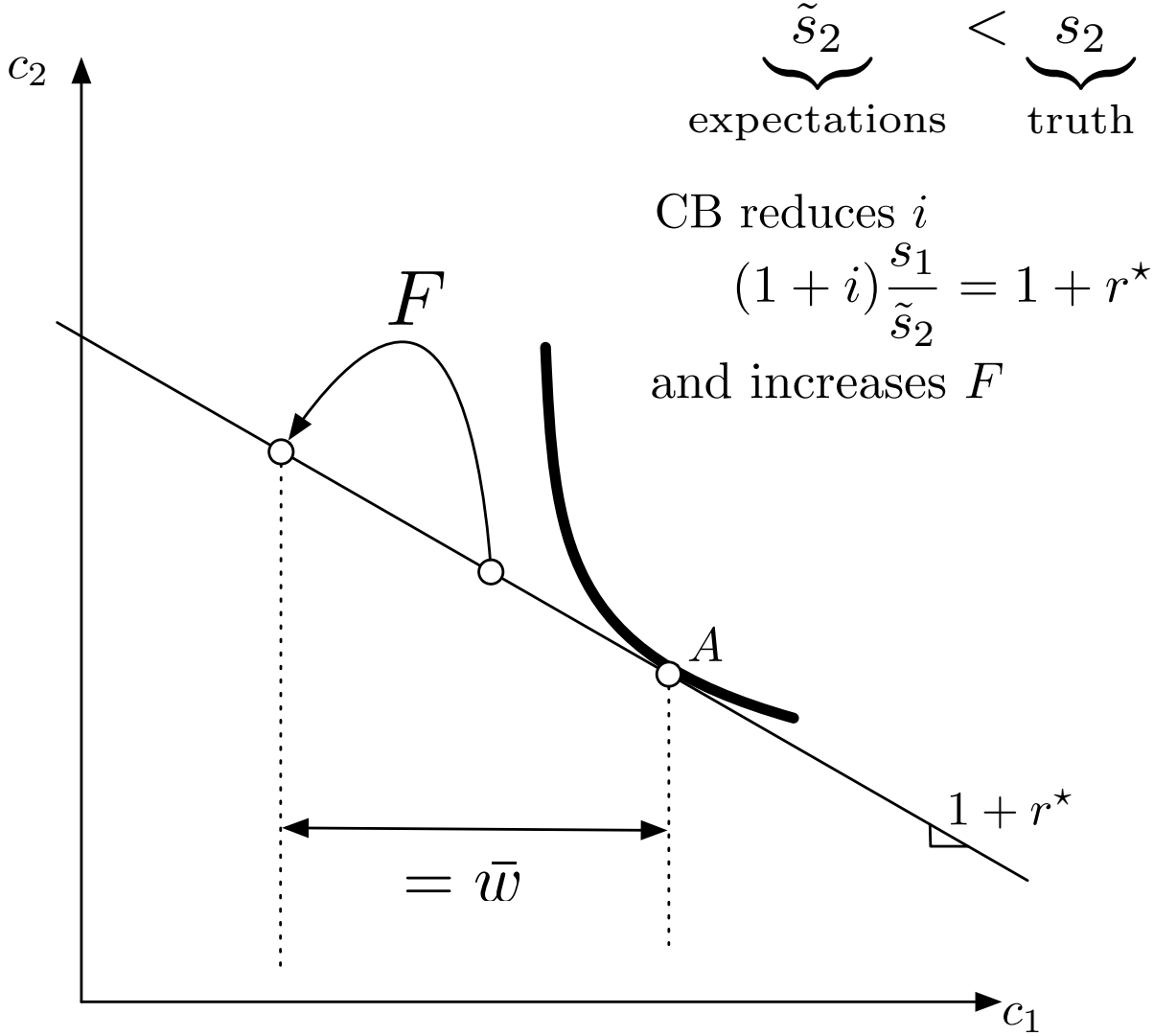
Irrational expectations away from ZLB



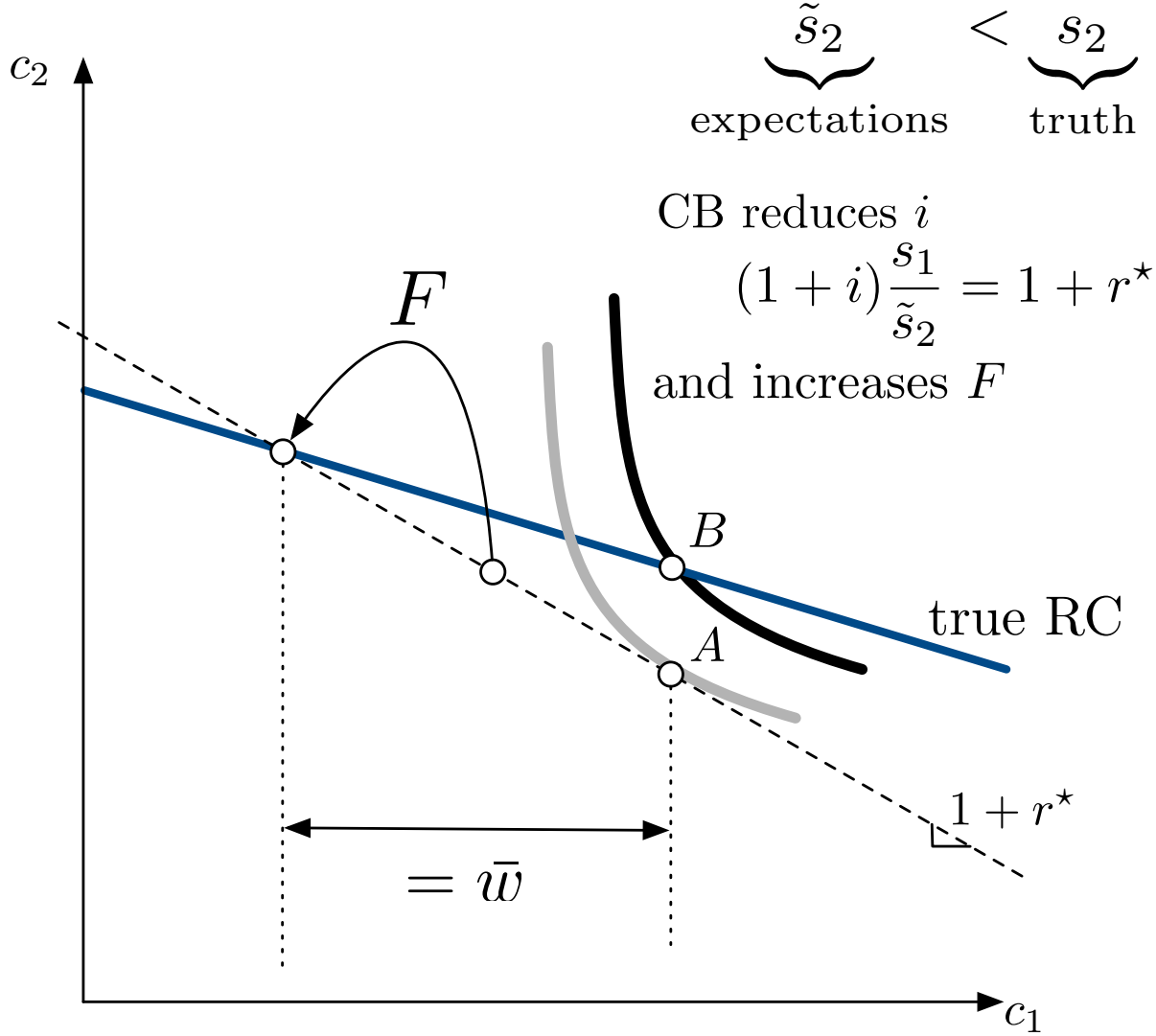
Irrational expectations away from ZLB



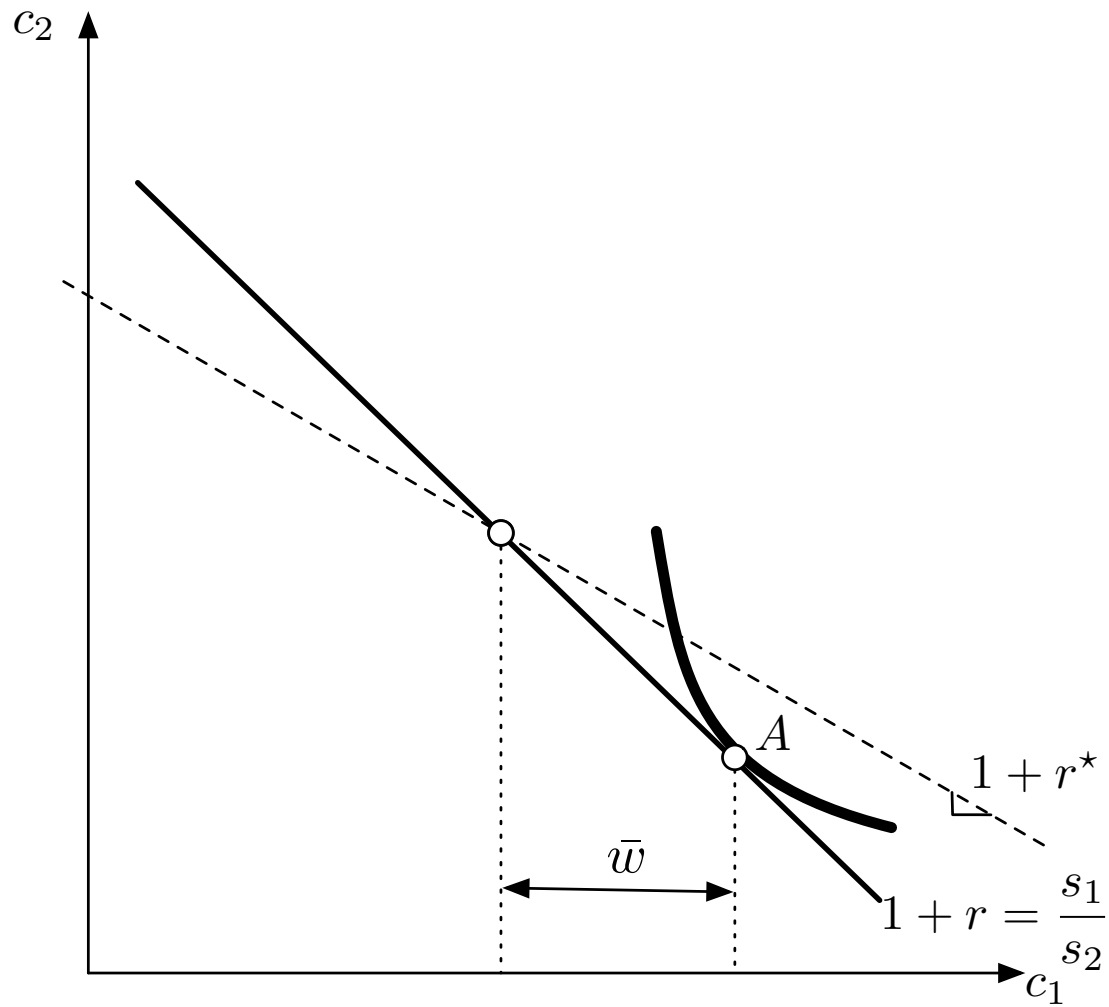
Irrational expectations away from ZLB



Irrational expectations away from ZLB



Irrational expectations at the ZLB



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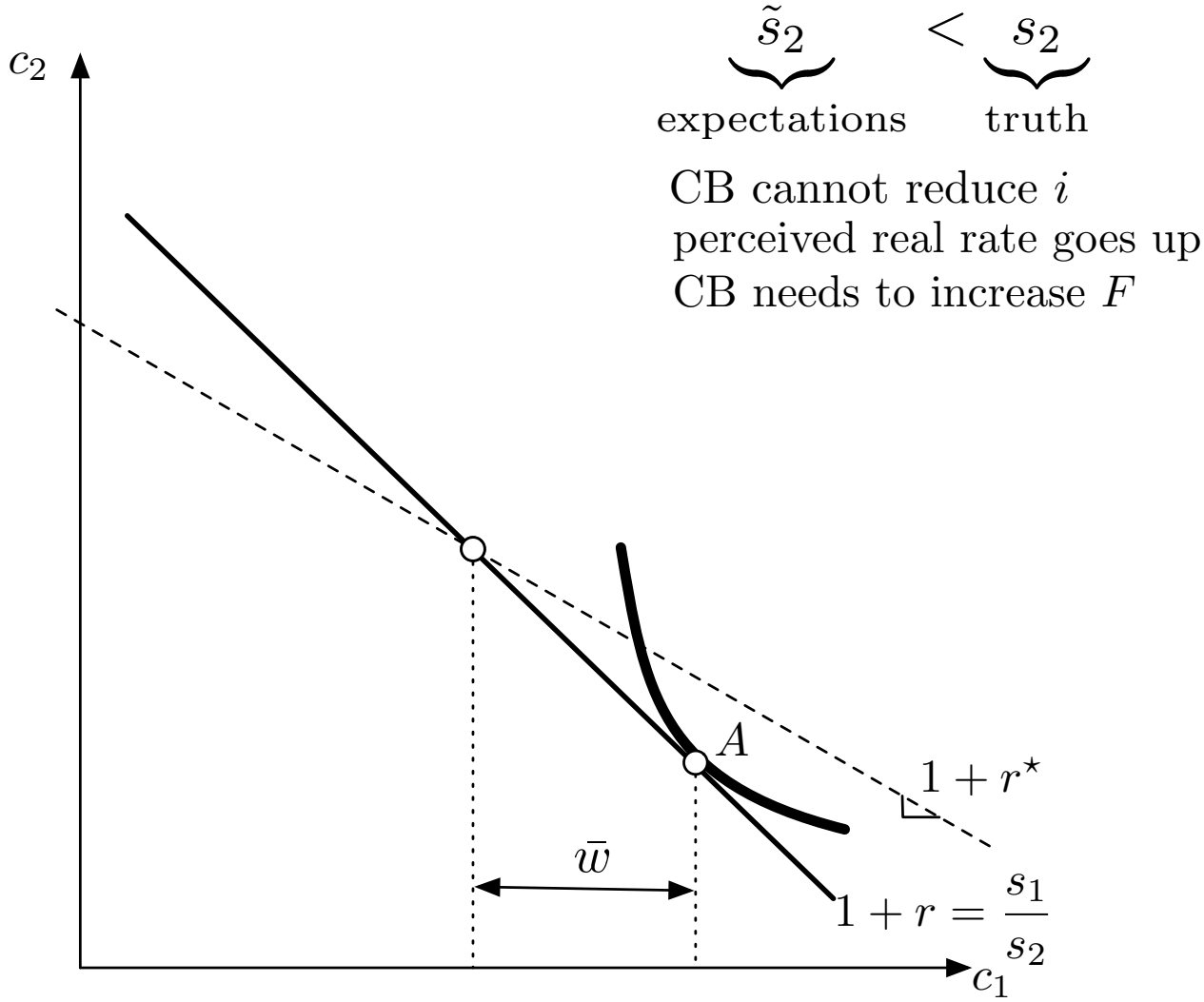
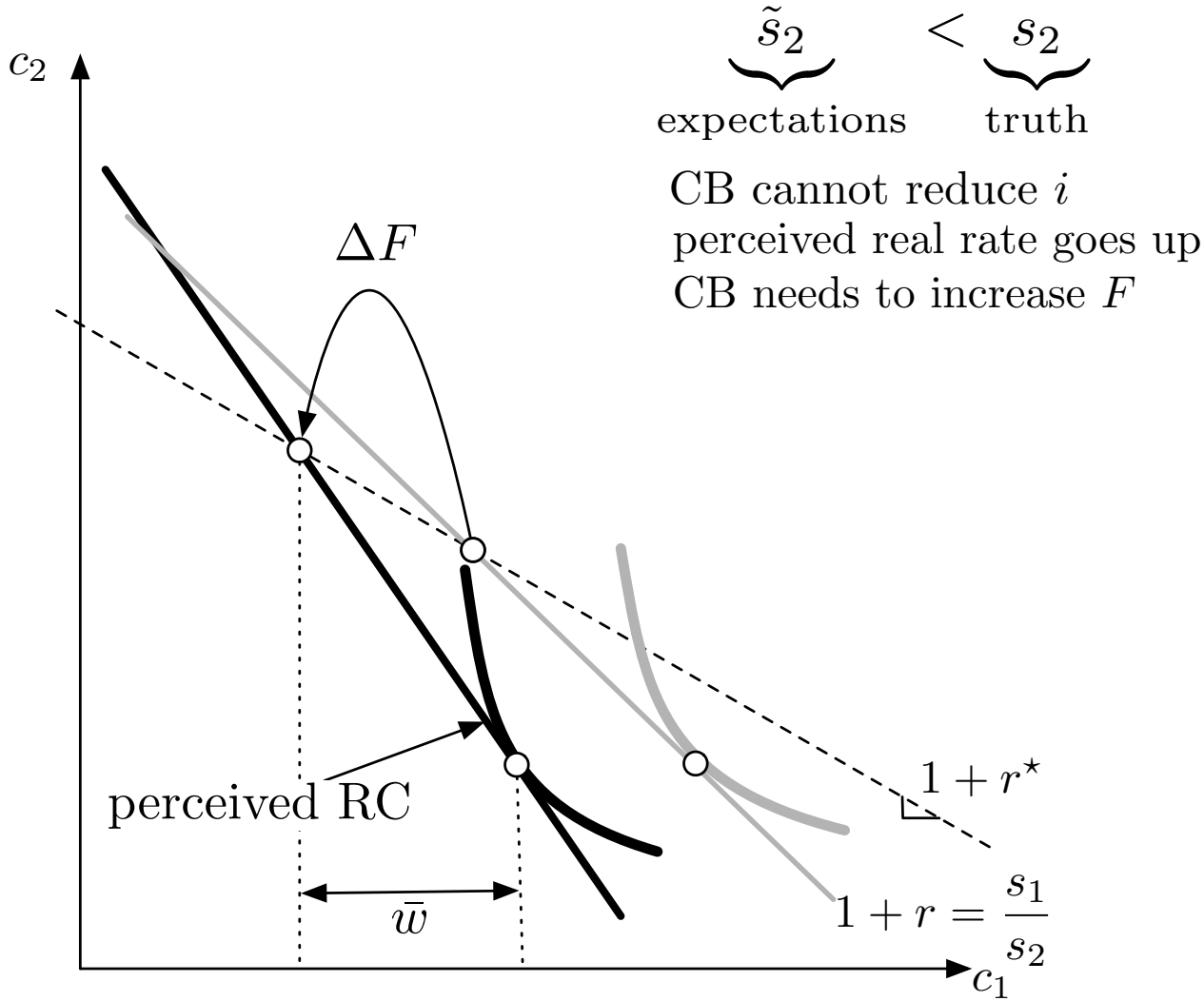
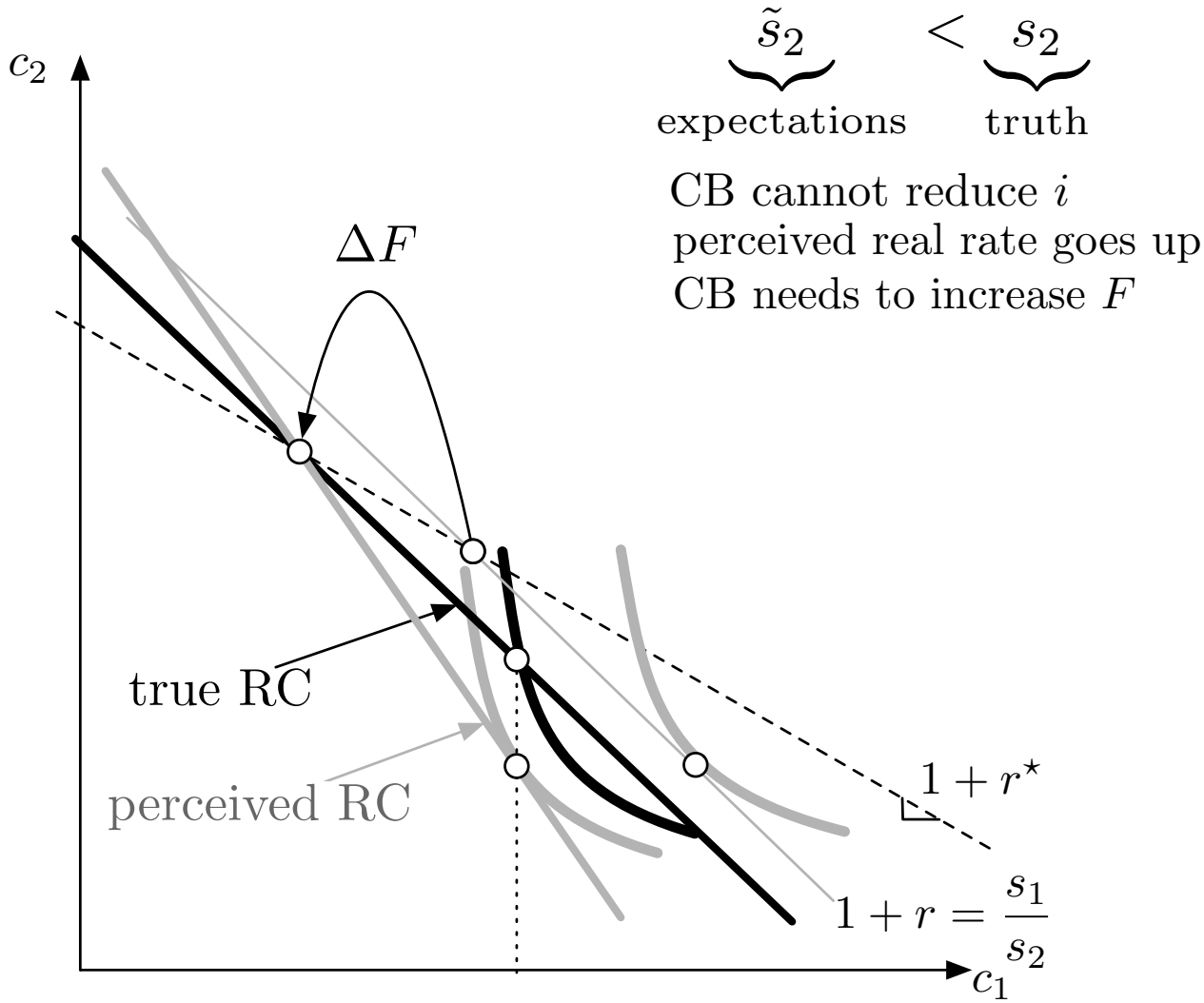


Irrational expectations at the ZLB



Irrational expectations at the ZLB



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